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Published monthly by the
University of the State of New York
BULLETIN 259 JULY 1902

New York State Museum

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John M. Clarke State paleontologist

Bulletin 52 v.10

PALEONTOLOGY 6

REPORT OF THE STATE PALEONTOLOGIST

1901

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1902

Mp102m-D1-1500

Price 40 cents

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JOHN M. CLARKE

State Paleontologist

STATE HALL, ALBANY, N. Y.

University of the State of New York

New York State Museum, Albany.

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Museum Bulletin 52 April 1902

REPORT OF THE STATE PALEONTOLOGIST 1901

To the Regents of the University of the State of New York

I have the honor to report herewith on the work of this department during the year commencing Oct. 1, 1900.

Operations in the field 1900-1

Investigation of problems pertaining to the fauna of the Ithaca group of central New York. In my report of last year notice was taken of the fact that the legislature of that year had provided for investigations having special reference to the relations of the Ithaca formation and its fauna to contemporaneous organic and inorganic conditions at the east and west of the central New York area as well as to such conditions as immediately preceded and succeeded them in time. As a preliminary step to the solution of the problems involved, which were stated in some fulness in the report referred to, it was essential that extensive collections be made from the fossiliferous strata throughout the various outcrops of this district. For a large part of the season of 1900 this work was carried on, specially in the region from Otsego county westward into the Chenango valley and into the valley of the Tioughnioga river. The material sent in as a result of this work, largely acquired by D. D. Luther, field assistant, was in many respects of high paleontologic interest, not alone in bringing to our attention organic forms hitherto unknown in our rocks, but specially in completing series which clearly point to the fact and the course of development and variation of early species into later. In

view of the unusual conditions under which the sediments in this part of the state were deposited, and under which its organisms flourished on these ancient sea bottoms, the lessons to be derived from the results hitherto acquired are very instructive. Furthermore, besides the novelty of much of the material thus brought together, we have acquired for the collections of the state museum an important new element; for in the past the fossils of this Ithaca formation have been largely confused with the organisms from the rocks beneath, and up to this time the state museum has had only the most meager and uncertain representation of this noteworthy element in the sequence of New York faunas.

The operations in this part of the state were not concluded with the closing of last season's work, and during the season of 1901 the investigations, so far as the acquisition of material is concerned, have been continued and completed by covering the region between the Tioughnioga river and the valley of Cayuga lake. This work of collection was carried on by C. A. Hartnagel with the assistance of H. S. Mattimore, and localities throughout southern Cayuga, western Cortland and Tompkins counties were carefully exploited. We have now the material for the elaboration of various peculiar problems which come into view relating to the origin and the destiny of this Ithaca fauna and also the data for confirming previously expressed views of its relations to the faunas of contemporaneous age which adjoin it on the east and west.

It may be here of special interest and usefulness to note that the period of time in which the Ithaca deposits were laid down, that is the Portage unit of time, was marked within the limitations of the state of New York by the manifestation of at least three distinct geographic faunal provinces, one in the east, the Oneonta province, where fresh-water conditions prevailed as in a coastal embayment or lagoon, receiving fresh-water drainage from the continental plateau; next west, the province of the true marine fauna which we know as the Ithaca fauna and which owes its derivation directly to the fauna which preceded it in time in this mediterranean sea or Appalachian gulf; and,

still farther westward, that of the Naples fauna, which is an invasion from the far northwest and occupies all the ground from the meridian of Cayuga lake to the shores of Lake Erie. Furthermore, the region occupied by the invading Naples fauna is clearly divisible into two subprovinces, that east of the Genesee river (Naples subprovince) into which the advance or herald species of the fauna penetrated, and the western (Chautauqua) subprovince, or that beyond the Genesee river, from which the advance species of the invasion had in notable measure departed on their journey eastward, but which those following in their train and pertaining to the same invading body had not passed. No parallel illustration of the intrusion of so diverse organic associations or faunas into an area so restricted as that here concerned between the valley of the Delaware river and the shores of Lake Erie is recorded so far as our present knowledge goes.

Study of waterlime strata and their fossil contents. During some years past study has been made of the character and variation in the succession of the waterlime series, which in our present classification of the New York rock series is regarded as pertaining to the geologic units termed Rondout and Manlius. The field investigations in this work have been carried on largely by D. D. Luther, and the results have been important in showing the degree to which the strata vary in character from one locality to another, but have been specially profitable in the light which they have thrown on the nature of the peculiar fauna inclosed by these sediments and in the new and interesting contributions to paleontologic facts which they have brought out. Several of the problems resulting from this series of field investigations have yet to be carefully studied to be appreciated in their full significance. Aside from the well known crustaceans (Eurypterus, Pterygotus, etc.) of these waterlimes which are produced in such remarkable perfection and profusion at the cement quarries at Buffalo, and in certain natural outcrops along the edge of the formation at Union Springs, Cayuga co., and Jerusalem hill, Herkimer co., the asso-

ciated species have received but comparatively little attention. The study of these has indicated the probability that we may not be altogether secure in the time-honored interpretation and correlation of some of our other strata having similar lithologic characters, such for example as the Coralline limestone of Schoharie county and the waterlimes of eastward sections. The fauna of a specially interesting outcrop of dark dolomite appearing on Frontenac island in Cayuga lake, where it is intercalated between the waterlime strata, will, when fully studied, give important aid in the interpretation of the proper relation of these beds to those which they immediately precede in time and to which they are otherwise allied, that is to the true Helderbergian strata. Collections were made at and about Jerusalem hill, and these operations were not concluded at the time of my last report. It may be briefly stated that the sum total of the latter work, which was devoted specially to the acquisition of the crustacean remains at this locality, has afforded us much interesting and unique material, not only increasing our knowledge of these unusual and peculiar creatures, but also yielding important evidence as to their early stages, their mode of development and habits of life. I note here the fact that from these collections we have obtained not only the most minute of these creatures yet recorded, but also the remains of the largest; heads of Eurypterus not $\frac{1}{10}$-inch across, indicating young forms not above $\frac{1}{2}$ inch in entire length and fragments of a single individual of the genus Pterygotus which could not have been less than 5 to 6 feet in length and thus representing one of the largest known of all invertebrate fossils, surpassing probably in size the similar crustacean, Stylonurus excelsior, whose parts have been found in the Catskill or late Devonic rocks of this state.

Paleontologic and stratigraphic map of Canandaigua lake region. In pursuance of a widely expressed desire on the part of many American geologists that the effort be made to portray on maps with more exactitude and fulness the paleontologic facts or actual succession of vital events in the earth's history, I have

undertaken to give a representation of such facts in a region that has been studied in great detail, perhaps with more care with reference to the succession of its fossil faunas than any other equal area in the state. The early maps of the sedimentary rocks of this state, like those prepared in other countries, combined all available data, organic and physical, for the delimitation of the formations; but the so called "geologic maps" of today do not attempt the representation of anything further than the succession of sediments or lithologic units. It is therefore, not possible that such a map tell the whole truth, for faunas do not vary *pari passu* with sediments. These geologic maps representing a succession of lithologic units display in a general way, it may be said, the facts which strike the ordinary observer most forcibly, such as the change in character of the rock, which may not however harmonize with the registration of the more essential facts of the earth's record; they are properly designated lithologic maps, as they express only variations in the character of the sedimentation. The true history of the earth is less the record of the successive changes in the nature of the materials that enter into the constitution of its crustal masses and of the physical events which have induced such changes, than it is a register of succession of the forms of life which have appeared on the earth in consecutive units of time. The history of the earth with this vital and organic element eliminated is the history of a body dead to begin with and always dead. Let it be invested with the manifestations of the life force in its manifold variations from the beginning to the present, and the earth's history becomes a record of vital interest.

Experience has further shown in the preparation of geologic maps in the state of New York, on the scale of the U. S. topographic base map, that this scale is either too large or our stratigraphic data are insufficiently refined. The quadrangles, stratigraphically colored, that we have thus far issued indicate this fact by displaying for the respective formations represented very broad bands of color with insufficient differentiation;

accurate in fact so far as the contacts of formations can at present be made out, but with inadequate detail in showing the changes and variations in the sediments and in the associations of the organisms they contained. It is not to be inferred that such maps are not of great usefulness. They are the most exact that we have thus far been able to produce and have unquestionably served a useful purpose to those who have had occasion to employ them.

In the region about Canandaigua lake, where years of careful study have given us a very detailed knowledge of the changes in sedimentation and the variations in the successive faunas, we have undertaken to color the two quadrangles known as the Canandaigua and Naples sheets, the former lying directly north of the latter and giving an area which completely encircles that lake and affords a rock succession from the horizon of the Salina gypsum beds upward into the basal beds of the Chemung, a vertical thickness of about 3000 feet. During the present season these sheets have been geologically colored, and the detail of the stratigraphy completed with all practicable accuracy; disregarding slight local changes, we have found it possible to represent variations in the sedimentation by a series of 26 colors, where, using the ordinary colors hitherto adopted, one for each of the usually recognized formations, nine or 10 would have sufficed. Corresponding with this detailed stratigraphic map on which it is planned to register every outcrop of the rocks as well as approximately every contact, I have prepared a map on the same base showing the succession and variation of faunas, or what may be termed a true paleontologic map. It is proposed to issue these maps as companion sheets and to illustrate by means of them the actual relation of major variations in faunas to variations in sedimentation. In the field work necessary for the completion of the stratigraphic part of this map, D. D. Luther has supplemented the records made by the paleontologist and himself during the last 20 years.

Areal geology of the Tully quadrangle. Early in the field season it seemed desirable for the purpose of accurate delineation

on the geologic map of the state, and to establish a base mark or guide for the plotting of the formations immediately above and below, to trace the outcrops of the Tully limestone from Owasco lake eastward into Madison county. Mr Luther was engaged for a short time in the work of locating these outcrops on the Tully and Cazenovia quadrangles. The Tully topographic sheet lies directly south of the Syracuse sheet and covers a very interesting section of the rock series. It has therefore seemed desirable to complete the areal work on this sheet, and this will be finished before the close of the present field season. The field work is in charge of Mr Luther.

Contact lines of formations in the region about Tonawanda and Oak Orchard creek swamps. The great swamp area lying east and west along the course of the Tonawanda creek and its branches and extending to the northeastward along the Oak Orchard creek and its tributaries, covering a vast acreage in the territory between Churchville at the east and Buffalo at the west, a distance of 75 miles, has naturally obscured the rock geology of a very large area in western New York. The question as to the direction and position of the actual contact lines of formations on which this lowland rests came up during the course of the season in the special consideration of a relatively new member in our succession of faunas lying at the top of the Niagara escarpment, the so called Guelph fauna of the Rochester section, to which fuller reference will be presently made. This depressed region, lying largely between the escarpments of the Lockport dolomites on the north and the Onondaga limestone on the south, has not been the subject of extended geologic investigation, and so far as my knowledge extends no careful traverses of it for the end which has now been in view, have been made since the early survey of 1836-43. The very great scarcity of outcrops, the depth of the drift mantle, and the generally unbroken and monotonous aspect of the country from a geologic point of view, have rendered the attempt to trace the formational contacts one of some difficulty. The paleontologist, accompanied by Dr Ruedemann and D. D.

Luther, has made a series of traverses across this region, zigzagging from the Niagara escarpment at the north back and forth along various meridians. It is perhaps not altogether a contribution to the geology of this region to state that the evidence obtained brings out quite clearly the fact that a proximate cause of this area of heavily timbered swamp land, which the state has unavailingly attempted to redeem, is the removal of vast amounts of soft shale at different geologic horizons, leaving as the actual rock bottom of the depressions a pavement or sill of heavy limestone; thus, by the removal of the Rochester shale which lies on top of the Clinton limestone, deep depressions running east and west along the strike of these formations were produced, and hence we find that some of the northerly branches of the swamp area, specially those of the Oak Orchard swamp, rest on a bottom of limestone from which this soft shale has been excavated. These areas are in a certain measure cut off from the large area of the swamp which has been produced by the removal of the soft Salina shale from the limestone or dolomites pertaining to the Niagara formation. Hence the great swamp area generally speaking lies on a pavement of Lockport dolomite, and by the outcropping ridges of this dolomite it is more or less distinctly cut off from the smaller swamp areas lying to the north. The removal of these large amounts of soft rock may be freely ascribed to erosion by stream action, and we find both in the Tonawanda and Oak Orchard creeks—streams whose main courses lie approximately east and west—a remnant of a force which would produce and probably has produced depressions of this kind along the strike of the rocks. While the removal of such large quantities of soft rock lying between formations of harder and more resistant texture may be looked on as the occasion for the existence of these swamps, the cause of their present actual extent and transgression of geologic barriers is doubtless to be found largely in more recent damming of the waterways required by the construction of the Erie canal, obstructing the natural drainage of the whole territory and rendering the actual run off insufficient and incomplete. In an appendix to this

report I have given further detail as to the results of field work in this area with special reference to locating the formational contact lines, and it may here be stated briefly, that the outcome of this work has been to correct in some important particulars these lines as heretofore registered on our geologic maps. Because of the scarcity of outcrops, however, the course of these contacts may always remain more or less conjectural.

Stratigraphic and paleontologic relations of Potsdam sandstone of the Lake Champlain basin to overlying limestones. During some years past Mr Gilbert van Ingen, special field assistant, has been concerned with the study of the fauna of the lower limestones of our rock series, specially those of the Beekmantown and the Chazy horizons as developed in the basin of Lake Champlain. These formations have furnished a large amount of new evidence as to the constitution of the faunas of the times they represent. Having acquired special familiarity with the faunas of these rocks, Mr van Ingen has at my request undertaken during the last season to study the relations which they bear to the underlying Potsdam sandstone, and to ascertain in how far the passage from the latter upward into the former is gradual and what evidence the fossils afford in regard to the transition of the earlier fauna to the later. The ultimate purpose of this inquiry is to determine to what degree the fauna of this ancient Potsdam period bears characters which may fix its age as Cambric. Historically this well known formation is the basal member of the "New York series of formations" as enunciated by the four geologists of the early survey. Dr Ebenezer Emmons, in defending, against the convictions of his colleagues, the existence of a series of still older fossiliferous sediments (the Taconic system) did not propose to embrace with them the Potsdam sandstone, a formation of which he also was the demonstrator. The Potsdam sandstone is furthermore clearly a shallow water or littoral deposit accumulated along the shelving shores of the most ancient crystalline continent, and is the oldest deposit of this character of which we have any knowledge in our rock series. Farther out at sea in the

deeper waters were laid down contemporary deposits, which doubtless included a richer congeries of organic forms. What these deeper water deposits were, where they are and what they contained are facts necessary to ascertain before we can arrive at a precise conception of the succession and correlation of our Cambric deposits. In a supplementary chapter Mr van Ingen has given a brief summary of his season's work on this problem.

Limestone lenses in the Clinton beds. In previous reports record is made of the fact that one of the problems under interrupted investigation by the department, is that relating to the origin of the peculiar lenses of unstratified semicrystalline limestone which have been observed at various outcrops along the Niagara cuesta from Lewiston to near Rochester. These lenticular masses of large size, often fully 30 feet in diameter, are either embedded in the well stratified and clearly jointed Clinton limestone, or lie near the upper surface of that limestone and are overlain by the shales of the Rochester beds. The occurrence of these peculiar rock forms, recorded first by Dr E. N. S. Ringueberg of Lockport and subsequently noted by G. K. Gilbert, their nature, origin and faunal composition have been the subject of study; and it has before been noted that a series of these rock bodies begins near Lewiston on the line of the Rome, Watertown & Ogdensburg railroad, where several are exposed, are seen also in beautiful display on the rock face along the line of the New York Central railroad just south of Lewiston, also at Gasport in considerable number, and at Middleport. Dr Ringueberg's early observations on the faunal contents of this peculiar rock served to indicate an association in some degree foreign to that of the rocks with which it is most intimately associated but with which it is never blended. The fauna is not that of the Clinton rocks of New York nor of the Rochester shales; though carrying a considerable representation of these faunas, its most conspicuous species are those which have been described as occurring in western faunas usually ascribed to the Niagara group. The observations on

these lenses which were made by the paleontologist in 1899 and 1900 have been supplemented during the last year by a fuller and more careful study of the field conditions by Prof. A. W. Grabau of Columbia university. Dr Grabau has had as associates in this work H. W. Shimer of Columbia university, R. F. Morgan of Buffalo, T. W. Peirson of Lockport and Charles Ewing of Middleport, all of whom in this work volunteered their services.

Evidence of these lenses has been found at Lockport; on the east side of the "gulf" and north of the Niagara road is an exposure of several of them lying on the shelf formed by the Clinton limestones. One of these could be located only by presumption, as its site seems to be covered by the embankment of the new electric railroad. Two other lenses are exposed within a short distance of each other, and these apparently rest on the surface of the Clinton limestone. The greatest thickness of these two bodies was 3 to 4 feet, though this may have been reduced by long weathering. Compared with the lens outcrops farther west in the vicinity of Lewiston, these at Lockport did not prove very fossiliferous, the principal fossils being Lichenalia and Whitfieldella nitida. The lithologic structure of the rock however, a subcrystalline, unstratified mass of hardened, calcareo-magnesian mud, is very characteristic and in harmony with the traits displayed at other localities. Heretofore actual exposures of these lenses have not been recorded at Lockport, Dr Ringueberg's original description having cited only loose blocks of this material in this neighborhood. In the northern part of the city of Lockport, in the rear of William Stamp's lot on Jackson street, and on land owned by Mr Mansfield, several large masses of the same rock are exposed. These rest on the limestone ledges of the Clinton, which here form a shelf of some width. This exposure would seem to indicate not less than two separate rock bodies.

Between Lockport and Gasport none of these lenses have been seen, exposures everywhere being unfavorable for their exhibi-

tion. In the ravine of a branch of Eighteen Mile creek south of Gasport lenses are of very frequent occurrence, as I have noted in a previous report. East of the road leading south from the village, along the edge of the stream a number of these, stated by Dr Grabau to be not less than 20, have been observed within the space of ½ mile, and others appear in the ravine west of the road. These all lie in the upper part of the Clinton limestone, and the majority are shown in the bed of the stream, the original covering of the limestone having been entirely removed, though some still show the covering layers of the limestone for a foot or so in thickness, arching upward over the lens, forming a domed surface of exposure. A similar phenomenon is observable in the occurrence on the New York Central railroad at Lewiston, where the arch and dome are formed by the Niagara shale. At Gasport fossils are more abundant in the lenses. At Middleport no other evidence of the lenses is to be found than the single one located by the paleontologist two years ago and largely removed at that time for the purpose of obtaining its fossils. This lies on Jeddo creek on the land of Mr Ewing and appears to rest on top of the upper Clinton limestone and to be covered by the Rochester shale. Though the shale has been removed from the lens itself, a bank of it is not far away, and evidence of it is present about the edges and on the lower side of the lens.

There is some evidence of variation in the character of the fossil contents of these rock bodies, according to geographic position. Those on the Rome, Watertown & Ogdensburg railroad near Lewiston appear to be the most highly fossiliferous of all, parts of them being impregnated with masses of separated shields of the trilobite Illaenus, which have been washed together and piled up like saucers; they are also very rich in cephalopods of unusual species, (Orthoceracones and Cyrtoceracones), brachiopods, etc. These species are apparently less abundant in the lenses at Middleport and Gasport; but we are not at present able, from the evidence in hand, to determine in how far there is a meridional variation in

the fossil contents of the series of lenses. Dr Grabau and his assistants have sent in a considerable amount of material which will aid in the solution of the organic feature of the problem. The observations thus far made on these lenticular bodies seem to indicate that they were substantially hardened masses in the sea bottom before the succeeding deposits were laid down over them. It may be said with comparative security, that the faunal content was in considerable measure an importation from the west or southwest. To what degree the sediments were tidal barriers, and the concentration of the fauna in this peculiar form due to the dragging action of tidal currents or accumulation by other mechanical action, and in how far the species represent an actual brief invasion, is yet to be determined.

Phenomena of like character to those rock masses are found in the "Klintar" which constitute striking headlands on the sea wall of the island of Gothland in the Baltic sea. These are lenticular masses of dolomites without sedimentation structure, lying involved in upper Siluric strata of age equivalent to that of the Clinton and Rochester beds of New York. They have been shown by Wiman[1] to be the product of reef-building organisms (corals and bryozoans), though now by wave detrition and by dolomitization but faint trace of such organic structures appears in the rock itself. The Clinton reefs are so impregnated with organisms of form unusual to the contemporaneous deposits of the western New York province as to raise the question above referred to concerning the influence of tidal currents in spreading out on these barriers extralimital organisms from adjoining provinces.[2]

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[1] Ueker silur. Korallenrippe in Gotland. Geol. instit. Upsala. 1897. v.3. pt 2, p. 311.

[2] Since the above paragraphs were written, the nature of these peculiar rock masses of the Clinton beds has been made the subject of a careful paper prepared by C. J. Sarle (Am. geol. Aug. 1901. p. 282). The author has registered the occurrence of a considerable number of these rock bodies and has brought together much evidence confirmatory of their reef structure.

Guelph horizon and its fauna in the sections at Rochester and westward. At the meeting of the American association for the advancement of science at Rochester in 1893, Prof. Albert L. Arey, then of the Rochester free academy, now of the Brooklyn girls high school, drew the attention of the geologists present to his discovery of a fauna lying in strata at the top of the Lockport dolomite series. These fossils, remarkable for the beauty of their preservation, were obtained by Prof. Arey in nodules of white chert found in the upper dolomite layers at a quarry in the southwest part of the city, then being worked and known as Nellis's quarry, and also from excavations for municipal improvements made in the southern streets of the city. Shortly after this discovery a representative series of the fossils was submitted to the paleontologist for examination, and it was then proposed that a joint description of this interesting new contribution to our New York faunas should be prepared. Subsequently the fauna was carefully studied by its discoverer and brought into comparison with the characteristic Guelph fauna, which is extensively and typically developed in the province of Ontario, and the results of this comparison, which did not extend to the details of specific identification, were set forth by Prof. Arey on the occasion referred to, and also published in the proceedings of the Rochester academy of science, vol. 18. Only an inkling of the presence of such a fauna in the New York rocks had before gone on record. As long ago as 1843[1] Prof. Hall noted the presence of certain species from what are believed to be the dolomites of this same horizon; and in that report and in his subsequent account of these fossils of the Niagara and Salina rocks in vol. 2 of the *Paleontology of New York*, they were ascribed to the beds of the so called "Onondaga salt group," the Salina formation of our present nomenclature. Prof. Hall's localities for these fossils were at or near Newark, Wayne co., but we have no other than the original record of them. Exposures of this upper narrow horizon along the summit of the

[1] Geol. N. Y. 4th dist.

Niagara escarpment are so rare, and the cuesta has been so seldom trenched either by natural or artificial means, that till Prof. Arey's discovery, it may be said that we were in almost complete ignorance of its presence. In and about Rochester the fauna seems to have attained a localized development to a profusion not observable elsewhere in the state. During the last year Prof. Arey has, with great consideration, placed his collections of those interesting fossils in the hands of the paleontologist for study. We have found that the material represents a fauna of about 50 species, of which 19 appeared (Niagaran) previously in the same locality, 4 are peculiar to the congeries itself, and 21 are present in common with the typical Guelph fauna of Ontario. It is thus clear that the fauna is not simply a local expression of a late stage of the Lockport dolomite fauna, but represents the true Guelph fauna of Ontario. It is possible that the collection we have had in hand does not fully exemplify the fauna, but, as Nellis's quarry is now abandoned, and there appear to be at present no excavations within the city of Rochester into this formation, we have been at a loss to add to the material already taken out from this region. Field investigations have been made with care for the purpose of tracing this horizon, which, it may be added, is hardly to be separated from the dolomites beneath by lithologic characters, to the west and east of the vicinity of Rochester. The most complete section of the dolomites in the immediate vicinity of the city appears to be that on Allens creek just to the south, where shaly layers clearly referable to the basal beds of the Salina and chocolate colored dolomites which pertain to the Lockport dolomite series are exposed, but with a covered interval just where one would expect to find the Guelph horizon. In transecting the escarpment at various points between Rochester and Lockport slight traces have been found of the position of this stratigraphic horizon, specially at the excavations on the Orchard creek canal feeder south of Shelby, where the abundant nodules of white chert in the compact dolomite indicate species of similar character to those at Rochester but in a condition of less satisfactory preservation.

During the prosecution of this study of the New York Guelph horizon and the distribution of its fossils, typical localities in the province of Ontario were visited, the sections of the strata carefully studied and quite extensive collections made at Galt, Hespeler and Elora. The earliest fossils described from the Canadian sections were those given by James Hall in vol. 2, *Paleontology of New York.* Prof. Hall visited the region in 1847 before the stratigraphic relations of the series had been carefully studied by Sir William Logan and Robert Bell. Hence, in describing the organisms collected, he referred them to the "Onondaga salt group" together with the few remains taken from what he then believed and what has since proved to be the same horizon. The Canadian paleontologists, principally Dr Whiteaves, have given full accounts of the composition of the Guelph fauna, and at the time the collections were made for those studies, Elora and Hespeler were the most productive of the localities; latterly, through a diminished demand for the rock for construction purposes, less is now accessible at these localities in favorable condition for exploitation of the fauna, and neither is at present as interesting or productive as the various exposures about the beautiful village of Galt.

As shown here, the rock section begins on the east side of the bank of the Grand river just below the Grand Trunk railroad station (Ballantine's quarry and kiln), where are exposed, reading from the bottom:

1 A yellow, very sandy dolomite in compact layers carrying Megalomus in immense quantities and numerous gastropods, 10 feet;

2 Thinner and grayish slabby dolomites running up to and above the railroad track, 20 feet;

3 Darker, compact dolomite, 5 feet;

4 Thin, grayish yellow, slabby layers with gastropods, 10 feet.

The entire section from the river bank to the top of the bank above the limekiln is not less than 55 feet. This locality proved to be the best in the vicinity for the acquisition of the characteristic fossils of the fauna. The lower layers of yellow dolo-

mite when wet become softened, so that they break freely in any direction. The fossils, however, as everywhere in these rocks, are internal and external casts, and special pains were taken to secure specimens showing the characteristic exterior characters of the organisms.

On the opposite side of the Grand river are exposures at Hogg's and Webster's quarries, the latter a small opening of the basal layers on Crumby street, which furnished many interesting species. Just above the upper bridge on the east bank is a slight, unworked exposure of the upper compact, gray, slabby dolomite, which is profuse in gastropods. Melross's quarry, 1 mile north of the village on the east bank of the river, exposes a yellow dolomite 15 to 20 feet thick, running into a heavy bed toward the top. This rock is full of Megalomus, but good specimens of other fossils are not common, and gastropods less frequently seen. This outcrop lies about 2 miles north of Ballantine's quarry and is probably about 50 feet higher, completing the section at Galt, which can not be less than 100 feet thick.

All these outcrops are along the strike of the formation, and Sir William Logan regarded the strata here as representing the middle part of the group, those at Hespeler on the river Spree being in his judgment below this horizon, while the striking natural section at Elora, about the confluence of the Grand and Irvine rivers, where the canyon is not less than 100 feet deep, is considered the summit section of the formation. The series of fossils obtained from all these Guelph localities will constitute a useful addition to our museum collections.

Limestones of the Marcellus stage and origin of their faunas. The Marcellus formation is typically represented by a series of black bituminous shales, carrying a fauna which has peculiarities so well marked as to render it readily recognizable. Among these shales there occur in different sections interbedded limestones which are specially noteworthy for the diversity of their organic contents. Thus in eastern sections some 30 feet above the base of the shales lies the series of limestone banks which has been

known in geologic literature as the *Goniatite limestone*, or, employing the designation derived from the characteristic fossil of the rock, the *Agoniatites limestone*. These beds are most fully developed in the eastward counties of the state and gradually lose their individuality westward, disappearing just west of Seneca lake. While this limestone is absent in the western counties, another appears at a higher horizon in the shales and carries an altogether distinct series of fossils. To this limestone I applied some years ago the geographic name of Stafford limestone. We find in sections at the very base of the Marcellus sediments, specially in western New York, still a third impure calcareous deposit which was shown in the section of the Livonia salt shaft and recently has been exposed at Stony point south of Buffalo on Lake Erie. This also has a fauna peculiar to itself in many respects. Thus we have represented in this period of deposition several quite distinct faunal associations, and they have raised the interesting question as to how and whence these faunas have come into our state. The investigation of this proposition has been in a large measure a summarization of observations made by the paleontologist during the past years, but, in bringing these together for formal expression, much assistance has been received from Prin. John D. Wilson of Syracuse, who for some years past has been a diligent student of and collector from the Agoniatites limestone as exposed in Onondaga county and in his work has made some interesting contributions to our knowledge of the fauna of these layers. Some field operations in this connection have also been prosecuted in Schoharie and Otsego counties with interesting results, as detailed in a paper on this topic, communicated in museum bulletin 49, which is also accompanied by an account of the section of the Marcellus limestones as exposed at Lancaster, Erie co., by Miss Elvira Wood, instructor in paleontology in the Massachusetts institute of technology, an investigation which the author has executed with care and exactitude.

Character of the so called Hudson river beds of the northern Hudson valley. In continuation of the study of the nature and composition of the formation which has been known in geologic

literature as the *Hudson river slates*, Rudolf Ruedemann, assistant paleontologist, has extended the work previously done and reported on, in the vicinity and to the south of Albany (museum bulletin 42) northward into the upper reaches of the Hudson valley and the general field of exposure of the formation in this direction. On the west side of the river the Lorraine and Utica beds have been traced as far as Mechanicsville; on the east side the Utica, middle Trenton and Normans kill shale were followed only a few miles northward to the long outcrops on the Deep kill in Rensselaer county. At this point a most interesting discovery was made in the finding of beds containing a very unusual graptolite fauna in a fine state of preservation; such a fauna as was described at an early date by the late Prof. Hall from the so called Quebec shales of Canada. Of this fauna nothing has before been known in the state of New York, and the presence of these fossils here in such abundance affords not only important points of correlation of the New York with the Canadian faunas, but again adds in a notable and interesting way to the ancient faunas of the state. Though this fauna is embedded in the "Hudson river slates", its age as indicated by the character of its fossils is doubtless to be ascribed to that of the Beekmantown formation, and represents in an unbroken succession the faunas of horizons which have hitherto in America been known only separately and without any clue to their chronologic sequence. From a biologic point of view the interest of the discovery is greatly enhanced by the presence of innumerable growth stages representing the entire development phases of many forms, from the embryonic stage to the fully developed colony. This interesting section occurs near the town of Melrose in northwestern Rensselaer county, and its graptolites are representatives of the genera Phyllograptus, Tetragraptus, Loganograptus, Dichograptus, etc., which have hitherto been foreign to our faunas. Four different aggregations of graptolite-bearing shales were found in the thick mass of thin bedded limestones and greenish grits which compose the outcrop; and, as the aggregations or faunules are

distinct in their composition, it is believed that exact correlations will be possible even with regions so remote as the sections in Scandinavia, on the continent of Europe and in Australia, for these organisms seem to have maintained to a degree not displayed by others their value as time-markers in the succession of the early Siluric rocks.

1 The lowest horizon is characterized by innumerable examples of Didymograptus, specially D. nitidus and D. patulus.

2 The next fossil-bearing beds are the richest in species, and the state of preservation is the most excellent. They contain a Tetragraptus and Dichograptus fauna, nearly all the species of these genera, which were described by Hall from the Quebec beds, and several additional ones being present. The fauna of these two horizons combined is that reported from the "main Point Levis zone" of Hall. This has been referred to the lower Calciferous or Beekmantown formation.

3 Farther up the creek is another series of graptolite beds characterized by Didymograptus bifidus and Phyllograptus anna, these two species comprising the majority of all specimens. Neither of them occurs in the first two horizons, but they are characteristic forms of the Phyllograptus anna zone of St Anne river, Quebec.

4 Next follows the great mass of the quarry beds consisting of heavy banks of greenish grits with thin shaly partings, the latter carrying innumerable specimens of Phyllograptus typus, P. anna and P. angustifolius. Besides these Didymograptus bifidus, D. similis, Thamnograptus anna and others. They probably represent the upper part of the Phyllograptus anna zone.

5 About 800 feet farther up the creek are two narrow black bands intercalated in the dark greenish gray, barren shales, which carry a very luxuriant assemblage of fossils, having not less than 18 species, all of which are new to the New York faunas. Two of these are brachiopods, viz: Lingula quebecensis and a large oboloid representing a new generic

form. The characteristic graptolite constituents of the fauna are Diplograptus pristiniformis, D. inutilis, Trigonograptus ensiformis, Cryptograptus antennarius, Retiograptus tentaculatus, Dictyonema, four new species belonging to the rare subgenus Desmograptus, hitherto represented by but a single species in America. This association of forms which is made strikingly distinct by the introduction of the diprionid element appears to be identical with one mentioned by Prof. Hall as occurring at Point Levis, and which is correlated by Gurley in his list of the North American graptolites with the upper Beekmantown horizon. Thus the zones which have elsewhere been held to represent lower, middle and upper Beekmantown horizons are here exposed in continuous section. It is hoped that a more extended study of these beds will furnish the data for an exact determination and subdivision of the graptolite horizons throughout the Beekmantown formation, and it is also purposed to present a careful paleontologic study of the graptolites themselves. In the appendix to this report Dr Ruedemann analyzes the section in greater detail and also gives under separate title an account of the development of one of the graptolite species, Goniograptus thureaui.

Monroe mastodon. Late last season my attention was called to the discovery of mastodon bones which had been made some time previously near the village of Monroe, Orange co., on land belonging to Martin Konnight. On visiting the spot, it was ascertained that the bones found were in the possession of George Konnight of Monroe and had been taken some years ago, while drawing muck from a pond bottom which had been exposed by a protracted season of drought. All the bones obtained at that time had been kept together with care by Mr Konnight. The situation at Monroe was as follows. Just below the village at the north side of the highway leading to Turner, lies a pond about 250 feet in diameter containing, at the times of my visits, water to an average depth of 6 feet. On careful study of the topography of the region, it seemed prob-

able that this pond was cut off entirely from the lowland in the immediate vicinity, though the highway was tangent to its southern border, and below the highway the land spread off into a broad, gentle depression. The pond had no visible outlet, though it was pretty clear that the water found its way by seepage across the highway into the lowland beyond, and, as there was no visible surface inlet into the pond, it was a natural inference that the water was supplied to it mainly from the springs in the bottom.

Among the bones which were in the possession of Mr Konnight were the tusks of the upper jaw, which had become badly broken from long exposure but were still in condition to be mounted and which must have been from 8 to 9 feet in original length, the short tusks of the lower jaw, the occurrence of which is of very great rarity among these fossils, several ribs, a scapula, a tibia and other leg bones, some of the bones of the feet, etc. all of which except the upper tusks were in a condition of superior preservation. On comparison of their dimensions with those of some of the more complete mastodon skeletons, they indicated a skeleton of very great size, almost if not quite reaching the size of the Warren mastodon, the largest yet obtained from the surficial deposits of New York. The legislature was asked for an appropriation of $600 to effect the emptying of the pond and the excavation for the remaining bones, the fact being recognized that the accumulation of bones from so many parts of the body as were represented by those in Mr Konnight's possession, indicated a favorable opportunity for the acquisition of the remainder. This appropriation having been granted, the work of emptying the pond was begun in June and when all these preliminary operations were concluded the excavation of the muck in the bottom was begun. The labor of removing the water and keeping it out of the pond proved extremely arduous, as the water was found to enter the pond by several very large springs, and it was necessary, in order to keep the pond basin free of water, to work the gangs at the pump both night and day. This undertaking occupied a month

or five weeks, and the expense attending it was in excess of the estimate, so that, when excavation became possible, our means did not enable us to carry this to completion. The area of about one third of the pond bottom was carefully dug over, and additional evidences of the mastodon skeleton were found; but, as we had reached the limit of our appropriation and were in danger of passing beyond it and incurring an expense which could not well be borne, and as I was unable to obtain additional assistance from any private source, it became necessary for us to end the work with the excavations incomplete. Hunting mastodon skeletons carries with it a large element of uncertainty, as such skeletons are very rarely complete. The fluidity of the soil in which they have become mired disjoints and scatters the bones, with the result that the finding of one part or a considerable portion of a skeleton does not guarantee the presence of all the bones. The parts we have obtained have features of considerable interest, specially the lower incisors to which reference has been made, and the possibility of reclaiming the remainder of the bones is still about as good as it was at the beginning of the enterprise.

Cooperative work with the U. S. geological survey on the Salamanca quadrangle. In the season of 1900 the work which had been undertaken on the areal geology of the Olean topographic sheet was brought to completion, and the results carefully worked out both here and by the representative of the U. S. geological survey, Prof. L. C. Glenn. This work and report thereon will be published during the coming year. With the opening of the present season the work was continued to the adjoining quadrangle on the west (Salamanca), in which Prof. Glenn was associated with Myron L. Fuller of the U. S. geological survey. Charles Butts, who had during the previous season been the representative of this department in that work and who had prosecuted the stratigraphic and paleontologic determinations in the office during the winter, had in the meantime received an appointment as assistant geologist on the U. S. geological survey, but by the concession of M. R. Campbell, geologist in

charge of the work throughout this region and northern Pennsylvania. Mr Butts has been allowed to represent us in the acquisition of material necessary for paleontologic determinations from localities in the Salamanca area.

The work in the field as originally planned when the appropriation was made has now been brought to completion, and there remains but the summarization of the results acquired and the detailed representation of the stratigraphy on the topographic sheets. This will be the work during the coming winter of Prof. L. C. Glenn, and the completed map will be communicated to this department for publication, together with an explanatory statement of the detailed stratigraphic observations. Further reference is made under the head of office work to some of the paleontologic and stratigraphic results obtained from the work on the Olean sheet.

Personnel of the field staff

In the field operations of the department during the last season the following men, outside the permanent staff of the department, have been engaged: Prof. Charles Butts and Prof. Myron L. Fuller of the U. S. geological survey, on the work in Cattaraugus county; Prof. A. W. Grabau of Columbia university with H. W. Shimer of Columbia university, R. F. Morgan of Buffalo, Charles Ewing of Middleport and T. W. Pierson of Lockport on the investigation of the Clinton lenses in Niagara county; Gilbert van Ingen in the study of the Lower Siluric of the Champlain basin; C. A. Hartnagel of Hornellsville on the Ithaca group problems in Tompkins and adjoining counties.

Office work

Publications. The reports which were left unfinished at the time of the death of the late state geologist and paleontologist, Prof. James Hall, have now been brought to a conclusion and are all printed and issued. In regard to the memoir on the *Generic structure of the Paleozoic corals* which Prof. Hall had planned, I am able to report additional progress in spite of

obstacles to the satisfactory execution of the undertaking which have arisen. In the completion and final revision of this work some serious difficulties have constantly recurred because of the incertitude involving many of the specimens on which the investigations have been based, partly with reference to their actual geologic position and partly relating to their geographic locality. The material with which it was expected that the investigations would be continued belonged largely to the collection of Prof. Hall, and only a small part of this material has been since his death available for these studies. Notwithstanding these and other difficulties pertaining to its execution, I believe it practicable to present this subject in a form useful to students.

During the last year the following publications have issued from the department:

The annual reports for the years 1899 and 1900.

Museum bulletin 39, containing a number of papers relating to paleontologic and stratigraphic problems, as follows:

A remarkable occurrence of Orthoceras in the Oneonta beds of the Chenango valley, N. Y.;

Paropsonema cryptophya, a peculiar echinoderm from the Intumescens-zone (Portage beds) of western New York;

Dictyonine hexactinellid sponges from the Upper Devonic of New York, and

The water biscuit of Squaw island, Canandaigua lake, N. Y., by John M. Clarke;

Preliminary descriptions of new genera of Paleozoic rugose corals, by George B. Simpson;

Siluric fungi from western New York, by Frederick B. Loomis.

Museum bulletin 42, entitled the Hudson river beds near Albany and their taxonomic equivalents, by R. Ruedemann.

Museum memoir 3, entitled the Oriskany fauna of Becraft mountain, Columbia co. N. Y., by John M. Clarke.

Museum bulletin 45, Guide to the geology and paleontology of Niagara falls, by A. W. Grabau.

At the present time there are in press:

Bulletin 49, containing a series of paleontologic papers entitled:

On the Trenton conglomerate of Rysedorph hill, Rensselaer co., N. Y. and its fauna, by Rudolf Ruedemann;

Limestones of central and western New York interbedded with bituminous shales of the Marcellus stage,

New agelacrinites, and

Amnigenia as an indicator of fresh-water conditions during the Devonic of New York, Ireland and the Rhineland, by John M. Clarke;

Marcellus limestones of Lancaster, Erie co., N. Y., by Elvira Wood.

Bulletin (as yet without number) being a catalogue of the types of Paleozoic fossils belonging to the New York state museum.

With reference to the last named publication I enter into some further detail.

Catalogue of type specimens. For nearly three years, as opportunity has afforded, we have been carefully compiling a catalogue of the type specimens of the Paleozoic fossils of the museum collections. Though many of these important objects had been brought together by themselves, a large number were found to be scattered, sometimes without distinguishing mark, through the collections both in the State hall and in Geological hall. It has consequently been an onerous task to identify these and bring them together. This work is now virtually done, and we have in press at the present writing the completed catalogue of all of this valuable material. It is the purpose to present this catalogue in a broad biologic arrangement and to supplement this with tables showing the geologic distribution of the organisms through the rock series. While probably every year will subject the list to supplementary additions, as the work progresses or as more careful examination of our extensive collections reveals additional type specimens, at the present time the following is a statement of our possessions of this kind.

Total number of type specimens of paleozoic organisms, 5044. These are divided as follows:

Plantae	43
Sponges	141
Coelenterata	348
Echinodermata	115
Bryozoa	484
Brachiopoda	1132
Lamellibranchiata	1022
Pteropoda	56
Gastropoda	374
Cephalopoda	571
Vermes	102
Crustacea	643
Pisces	13

It is well known that 25 years ago the late Prof. Hall sold his large collection of fossils, on which in very considerable measure the studies in the early volumes of the *Paleontology of New York* were based, to the American museum of natural history in New York city; and from this fact the impression has in some measure gone abroad that the greater number of types of the *Paleontology of New York* are not in Albany but in the museum at New York. It is therefore perhaps appropriate that attention be here directed to the following statement with reference to what may be termed types of the New York paleontology in the possession of these two museums, lest misapprehension continue in regard to the location of such specimens. The curators of the collections of Paleozoic fossils in the American museum of natural history have recently published a detailed catalogue of their type specimens from which we draw the following:

Total number of type specimens, Cambric to Devonic inclusive, 4067. Of these the types figured in official New York state publications are 3626; types from the Paleozoic rocks of New York state figured in official state publications, 2696.

Of the 5044 types of fossils, Cambric to Devonic, in the New York state museum about 4500 are from the Paleozoic rocks of New York state, and with very few exceptions were figured in the official publications of the museum. These statements seem to require no further comment.

Catalogue of fossil faunas of the state. During a part of the year Mr C. A. Hartnagel was engaged in the compilation of a card catalogue of the fossil faunas of all our paleozoic rocks. Such lists have never been prepared, and a catalogue has seemed to me imperative to enable us to note in how far our own collections retain the recorded representation of these faunal lists. The work is however not merely one of compilation, but requires for its perfection much careful review, and the elimination of the synonymous names, and really for its best usefulness, a grouping which shall be a better expression of the relations of the faunas than the mere bringing together of the species under the general names of the formations. The lists are very large, running up into the thousands of species, and it is believed that it will serve a useful purpose to put this eventually in published form, as has been done for the ancient faunas of other countries.

Determination of Rochester shale fossils from western New York. Mr Hartnagel was engaged for part of the year on the determination of the fossils contained in a large amount of material brought in from the Rochester shale of Middleport and other localities in western New York. As the representation of the fossils of this formation in the state museum has heretofore been somewhat meager, though containing many fine examples, this work has served to extend our knowledge of the fauna and has added a number of hitherto unrepresented species to our collections.

Study of fossils of the Ithaca formation. In connection with the problems relating to the Ithaca fauna, to which fuller reference has already been made, Mr Charles Butts was engaged for some time on the identification of the material collected during the season of 1900. Mr Butts's familiarity with the species of the

higher beds enabled him to undertake this identification with very satisfactory results.

Iron pyrites bed at the horizon of the Tully limestone in western New York. Recent investigations of the stratigraphy of the Devonic series in western New York has brought out the fact that, from the point at which the Tully limestone reaches its western extinction close on the eastern shore of Canandaigua lake and from there westward to Lake Erie, its position in the succession of strata is unfailingly marked by a deposit of iron pyrites in the form of a thin sheet an inch or two in thickness, becoming in places discontinuous and nodular. It proves as reliable a bench mark in the strata as does the limestone itself, always maintaining the position of the limestone as the boundary formation between the Hamilton shales beneath and the Genesee shales above. This pyrite is usually very compact and hard, and in many places among the twigs, balls and pellets of evidently concretionary nature are entangled considerable numbers of diminutive fossils. At the meeting of the American association for the advancement of science at Columbus in 1899, the writer called attention to this peculiar occurrence in the hope of eliciting some expression as to the probable origin of such a continuous deposit of this peculiar nature extending unbroken for almost 100 miles. Considering that the deposit preceded a period of evidently shallow, inclosed coastal areas or embayments, where organic decomposition proceeded in such a manner as to impregnate the muds with bituminous matter (represented in the black shales of the Genesee), it seemed natural to conclude that the environment which conditioned the formation of this iron sulfid was also due to excessive organic decomposition with generous liberation of iron oxids.

As long ago as 1885 the writer described a considerable number of organisms from this pyrite layer, recognizing the fact that they presented similarities to species of the preceding or Hamilton fauna, but their diminutive form seemed to render actual identification of them with previously known species insecure, and hence for the most part they were described as new

forms. The facts set forth have raised several interesting questions, among them the problem as to how far a fauna gradually or suddenly involved in such conditions as this deposit of metallic sulfid indicates could survive and with what modifications of form and structure life might be continued. We have found that the pyrite embraces representatives of various groups of animals, fishes, crustacea, brachiopods, gastropods, cephalopods, plants, etc., and all seem to have suffered in very much the same way from their surroundings, that is to say, with rare exceptions all have a diminutive size which may express an atrophy of function or an arrest of development. Some time ago I asked Dr F. B. Loomis of the biologic department of Amherst college to undertake the investigation of this problem. He has studied the matter with much care with material from various outcrops of the pyrite layer, has been enabled to free the organisms and identify them, and by a series of experiments has drawn some interesting conclusions as to the causes which have modified them and the conditions which prevailed over the sea bottom during the period of their life. Dr Loomis's results will be given in a future report.

Contributions to the geologic map of the state. In the compilation of a geologic map of the state by the state geologist, I have been pleased to place at his disposal all the data in the possession of this department which could in any way serve to render more accurate the delineation of the formational contact lines among the sedimentary rocks. These facts were those accumulated for this purpose by the late Prof. Hall and partly by myself under his supervision or independently. For the sake of the accuracy of this official map, I have also undertaken the determination by active field observations of some doubtful points, all in the hope that this map may, so far as the sedimentary rocks are concerned, express our best and most accurate knowledge of their distribution and classification.

Index to state publications on paleontology. The University has undertaken the preparation of an index or series of indexes to

the scientific papers issued under its supervision. To make this as complete as possible in its references to the paleontology of New York, I have undertaken to compile detailed references to the extensive literature of this subject, including references to descriptions of genera and species. To meet fully the purpose of such a compilation, it has seemed highly desirable that in this regard the list shall be exhaustive. The undertaking is one requiring considerable time, and it has been thus far carried forward in the intervals of more pressing work by Jacob Van Deloo, the clerk to the department.

Contraction of office quarters. Mar. 18, 1901, a bill was introduced in the assembly repealing ch. 355 of the laws of 1883, giving to the board of regents the supervision and control of such rooms in the State hall as were then or were to be occupied by the state museum. Apparent necessity for this legislation arose from the demand for room on the part of the state controller, the work of whose department had in certain directions become greatly enlarged by recent legislation. Before this bill passed the legislature, as it eventually did, provision was made in the supply bill to move the offices of the paleontologist and his staff to the second floor of the Geological hall. The items for this expense did not however meet the approval of the governor. Though we were thus left undisturbed, I desire to record here the fact that, at the time this proposition to remove our quarters was made, we occupied offices in the State hall with a floor space of 6822 square feet, divided among six rooms on the third floor and two rooms in the basement. Of the third floor rooms three of the largest were unsuited for any other purpose than storage on account of insufficient light. These with all the rest were filled with stacks of drawers containing the synoptic and special collections of the department. It was calculated at the time that the actual weight of the paleontologic specimens in this building, together with all movable furnishings and appurtenances of the department, was more than 250 tons. The failure of the appropriation referred to did not lessen the controller's need for more room; and, as the legis-

lative bill relieving the regents from the control of these rooms passed with the executive approval, we were soon thereafter called on to surrender as much space as possible for that purpose.

In previous reports I have repeatedly referred to the fact of the embarrassment to our work arising from the insufficiency of space to render our material, specially the recent acquisitions accruing from field work in actual operation, accessible for study. It has been a source of constantly increasing difficulty to adjust ourselves to these restricted and hampering conditions. However, in response to the controller's wishes, we have sacrificed 2000 square feet of floor space, including two of the three well lighted rooms, and, with all our effects in the contracted space remaining, are endeavoring to carry forward our work and to find place for our constantly growing collections.

The accessions accruing annually from necessary field operations are large, as these reports indicate; and the proposition to return to Geological hall, after having left it 20 years ago because the building was then regarded as overcrowded, involves a serious step backward. It is needless for me, under these oppressive surroundings, to renew a plea for appropriate quarters. The condition itself is an acute appeal therefor. Such quarters will come only with the construction of a modern and suitably equipped building for the museum, and this condition seems to be fully appreciated by all the friends of the institution.

Exhibit of the department at the Pan-American exposition. The department was called on to prepare an exhibit for the exposition at Buffalo. In response to this request an effort was made to bring together:

1 A series of the publications of the state relating to paleontology and stratigraphy.

2 The geologic maps issued by the department on the topographic quadrangles.

3 A series of the original drawings and plates of lithographs used in these publications.

4 Certain suites of fossils which it was thought could be displayed to best advantage with the least risk and would appeal best to the visiting public.

In addition thereto, there was prepared for this occasion an illustrated guide to the geology and paleontology of the Niagara falls and gorge.

With the cooperation of the Buffalo society of natural sciences, I brought together an extensive series of the remarkable crustaceans (Eurypterus, Ptergotus, Eusarcus, Erettopterus, Ceratiocaris) which are found in the waterlimes occurring at the well known cement quarries at Buffalo; and it is safe to say that no such collection of these remarkable and interesting objects was ever before brought together in one place. Great credit and much gratitude are due to the generosity of the Buffalo society in allowing their material from these rocks to be exhibited with that of the state museum in the completion of this series.

As a second exhibit of this kind, an extensive collection was prepared, to represent the fossil glass sponges which were the subject of a recently published state museum memoir. Here again we are placed under many obligations by the great consideration of E. B. Hall of Wellsville, the owner of a large number of characteristic and beautiful specimens of these fossils, which we supplemented in a measure with material from the state museum.

In the preparation of the guide to the geology and paleontology of Niagara falls and vicinity, we again had the cooperation of the Buffalo society of natural sciences. This work was placed in charge of Prof. A. W. Grabau, who made a special resurvey of the region and some special collections of fossils. The work was designed to treat of the origin of Niagara falls, its history and development, and incidentally the development of the topography of the adjoining region; a considerable part of the work was devoted to the stratigraphy and the character of the fossils, with abundant illustrations of all the species known to occur in the exposures along the gorge. As a whole the guide seemed well adapted

to the requirements of teachers, students and tourists generally; and the general demand for it is sufficient testimony of its usefulness. I am gratified to add that the exhibit of the department received the highest award, a gold medal.

Memorial tablet for the Emmons house, Albany N. Y.

It seems appropriate to take note here of the recent action of the American association for the advancement of science at its Denver meeting, August 1901, authorizing the placing of a bronze tablet on the house which formerly was the home of Dr Ebenezer Emmons, state geologist of New York in charge of the second geological district, 1836-42, to commemorate the fact that the association looks on this house as the place of its inception. The events leading up to this action are rehearsed in the following document, which is the report and recommendation made by the committee of the American association for the advancement of science, and adopted by that body.

REPORT OF COMMITTEE OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE ON THE EMMONS HOUSE MEMORIAL

The American association for the advancement of science was organized in 1847. It was the organic descendant and enlarged outgrowth from the Association of American geologists and naturalists. The latter body was created in 1842 by the incorporation of the naturalists within the Association of American geologists. The Association of American geologists is therefore to be looked upon as the legitimate organic ancestor of the American association for the advancement of science.

The circumstances which led up to the organization of the Association of American geologists are as follows:

During the prosecution of the geological survey of the state of New York the need of the geologists for consultation and interchange of view with others engaged in official geologic work led to the suggestion of an organization of a body of American geologists.

It appears that Lieut. W. W. Mather, one of the New York geologists, suggested the subject of such a meeting to the board of geologists in November 1838. He wrote:

"Would it not be well to suggest the propriety of a meeting of the geologists and other scientific men of our country at some central point next fall, say in New York or Philadelphia? There are many questions in our geology that will receive new light from friendly discussion and the combined observation of

various individuals who have noted them in different parts of our country. Such a meeting has been suggested by Prof. Hitchcock, and to me it seems desirable. It would undoubtedly be an advantage not only to science but to the several surveys that are now in progress and that may in future be organized. It would tend to make known our scientific men to each other personally, give them more confidence in each other and cause them to concentrate their observations on those questions that are of interest either in a scientific or economical point of view. More questions may be satisfactorily settled in a day by oral discussion in such a body than in a year by writing and publication." (Letter from W. W. Mather to the geological board of New York, dated Nov. 9, 1838, and addressed to Prof. Emmons)

It appears herein that the suggestion of this meeting was originally made by Pres. Edward Hitchcock of Massachusetts, who was the first to receive the appointment as geologist of the first district of New York from Gov. Marcy. Pres. Hitchcock has said in regard to the suggestion made by Lieut. Mather: "As to the credit he has here given me of having previously suggested the subject, I can only say that I had been in the habit for several years of making this meeting of scientific men a sort of hobby in my correspondence with such."[1]

Lieut. Mather's letter to the board of geologists was taken up for consideration at a meeting held Nov. 20, 1838, at the house of Dr Ebenezer Emmons, corner of High st. and Hudson av., Albany.[2]

The action taken by the geologists was one of unanimous approval of the proposition, and Lardner Vanuxem of the third district was commissioned to open communication with other geologists, specially with Pres. Hitchcock, with reference to carrying this project into effect. The undertaking was not immediately successful, and at a meeting held in the autumn of 1839 the purpose of the geological board was reiterated. This meeting was also held at Dr Emmons's house, the four geologists and the paleontologist being present, and also Ebenezer Emmons jr, who still survives. As a result of the second undertaking on the part of the New York geologists, a meeting was called in Philadelphia for April 1840, where and when the organization of the Association of American geologists was effected. The following year the association again met in Philadelphia, when the membership of the body was largely increased,

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[1]Address of Pres. Edward Hitchcock at the inauguration of Geological hall at Albany, Aug. 27, 1856. N. Y. state cabinet of natural history. 10th an. rep't. 1857. p. 23.

[2]*See* documents hereto appended, being A, a statement dictated by Prof. James Hall, Aug. 24, 1896, and B, a statement dictated by Ebenezer Emmons jr February 1900.

and in 1842 the place of meeting was Boston, and then, as already rehearsed, both the name and scope of the association were, at the solicitation of the naturalists, enlarged. Pres. Hitchcock, addressing the New York public interested in the outcome of the work of their geologists, makes the following statement in the address already quoted:

"It may be thought that the New York geologists in their invitation and the members of that first Philadelphia meeting had no thought of extending their association beyond geologists; but Prof. Mather's language just quoted speaks of 'a meeting of the geologists and other scientific men of our country', thus showing what were his aspirations, and they were shared by all of us who had anything to do with that first meeting. But we knew that only a short time previous the American academy of arts and sciences at Boston had directed a request to the American philosophical society as the oldest of the kind in the country, that it would invite the scientific men of the land to such a meeting as the one we are now enjoying; but the distinguished men of that society declined through fear that the effort would prove a failure. Surely then it did not become us to announce any such intentions or expectations; yet we did talk of them and could not but hope that what might fail if attempted on a large scale at first might be accomplished step by step. *Had not the New York geologists issued that modest invitation and confined it at first to the state surveyors, probably even yet we might have been without an Association for the advancement of science.*"[1]

The committee appointed by this association to consider the matter of placing a memorial tablet on the Emmons house in Albany N. Y. begs to submit the foregoing as evidence of the prenatal history of the American association and to recommend that this house, the home of the late Ebenezer Emmons, a man of eminence in his profession, of untiring diligence and enduring patience, be permanently marked by a tablet setting forth the interest of that spot to the history of the association. It is suggested that such tablet bear the following inscription:

IN THIS HOUSE, THE HOME OF
DR EBENEZER EMMONS,
THE FIRST FORMAL EFFORTS WERE MADE, IN
1838 AND 1839, TOWARD THE ORGANIZATION OF THE
ASSOCIATION OF AMERICAN GEOLOGISTS,
THE PARENT BODY OF THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,
BY WHOSE AUTHORITY THIS TABLET IS ERECTED.
1901

[1] Address of Pres. Edward Hitchcock, as cited.

The committee further reports that the cost of this tablet will constitute no claim on the treasury of the association but will be borne individually by one of its members, Dr T. Guilford Smith.

Signed by { JOHN M. CLARKE, *Chairman*
C. H. HITCHCOCK
J. McK. CATTELL
W. J. McGEE

A. Statement dictated to John M. Clarke by Prof. James Hall, Aug. 24, 1896.

The organization of a body of American geologists was proposed by the four geologists at Dr Emmons's house at the corner of Hudson av. and High st. It was during the fall of 1838. Vanuxem was asked to see or communicate with the Rogerses concerning it, but nothing came of it that year. The next year we reiterated our purpose, as the intention was to get some means of comparing our results with those of other geologists in other states, especially in Pennsylvania. This meeting was held at Dr Emmons's house, the four geologists being present and perhaps also Conrad. Ebenezer Emmons jr was also there. We then decided to communicate again with the Rogerses and others for the end already suggested and to organize a society of geologists for this especial purpose. We wanted to compare our results with those of others and make up our nomenclature, and we had to do it soon as we were required to publish. As a result of this unanimously expressed purpose, a meeting was called for April 1840 in Philadelphia. I was present then but not at the second Philadelphia meeting in 1841, as that year I was off in May and June with D. D. Owen on a flatboat sailing down the Ohio, sleeping on a box and collecting fossils all along from Louisville to New Harmony. As far as Rogers was concerned the meeting came to naught. He was not ready with his results and gave them only at the third meeting at Boston in 1842. It was here that the naturalists proposed to join us, and we agreed thereto, but the Boston meeting was called as the meeting of the Association of American geologists, and in the course of that meeting the name was changed to that of Association of American geologists and naturalists.

B. Statement dictated to John M. Clarke by Ebenezer Emmons jr, February 1900.

I was present at the meeting of the four geologists at my father's house, in 1838. I was then about 16 years old, and had assisted my father in his field work and making drawings

and sketches. Mr Conrad, the paleontologist, was also present. I recollect that the board of geologists then authorized Mr Vanuxem to open correspondence with others for the purpose of effecting an organization.

A bronze tablet measuring 14 by 24 inches has, in pursuance of this action, been placed on the old Emmons house, at the corner of Hudson av. and High st., Albany, and serves to commemorate in some measure the services to American science of the four state geologists of the geological survey of New York (1836-42).

Personnel of office staff

The staff of the office has remained as last year, with the addition to permanent position of D. D. Luther, who has been interruptedly employed in the department since 1891.

Rudolf Ruedemann, assistant paleontologist

D. D. Luther, field assistant

George B. Simpson, draftsman

Philip Ast, lithographer

Jacob Van Deloo, clerk

H. S. Mattimore, preparator and page

Martin Sheehy, machinist

Prof. Charles Butts and C. A. Hartnagel have been employed for parts of the year on special work.

It is with sincere regret that I have to record the death on Oct. 15, 1901, of George B. Simpson, draftsman, after an illness which kept him but a few days from his duties. The loss of Mr Simpson's important services is a serious deprivation to the work of the department.

Locality record of museum specimens

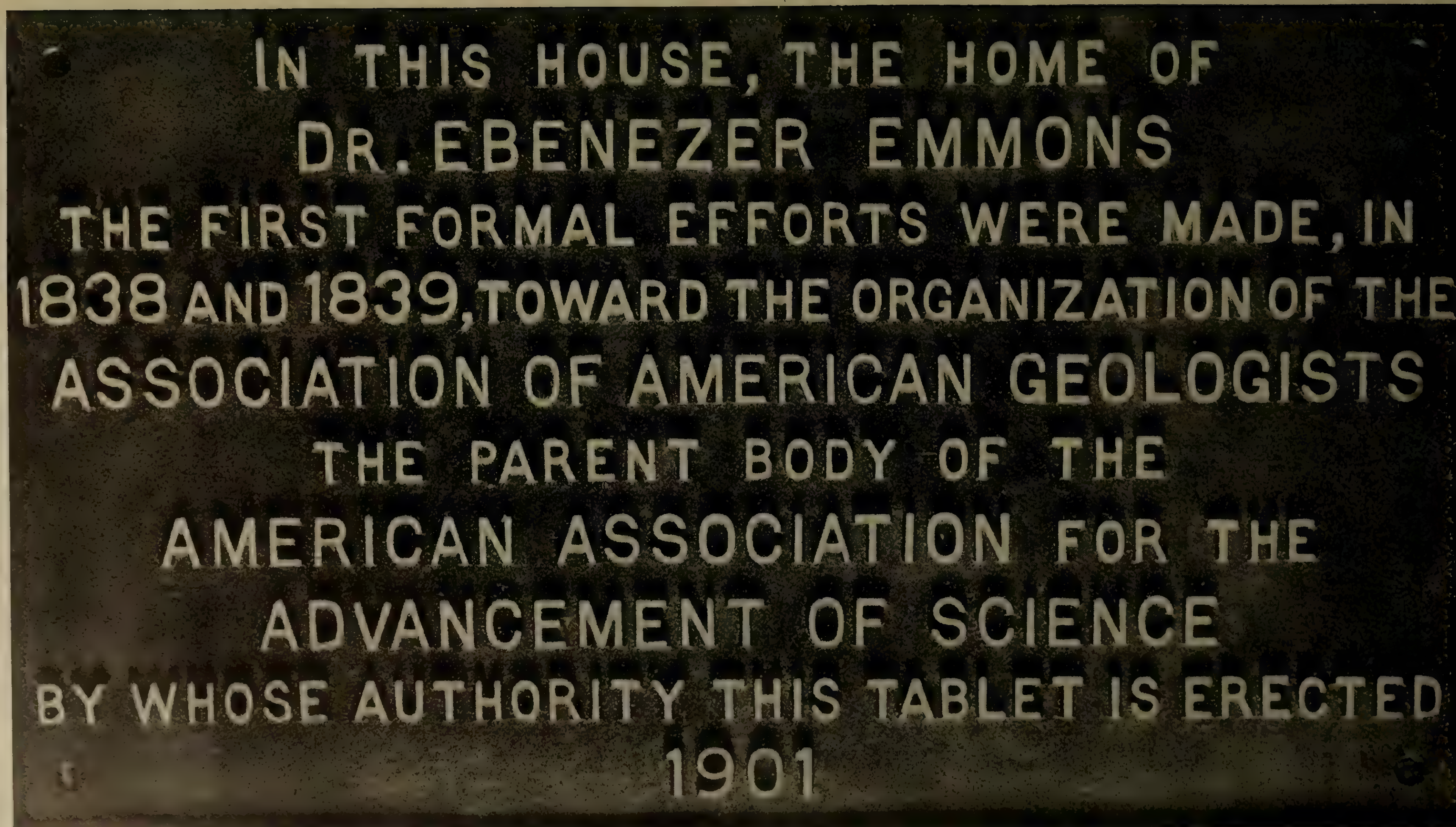
In continuation of the record of fossil-producing localities, parts of which have been communicated in my last two reports, I herewith submit a list of the additional localities entered during the course of the last year's work.

21 Oct. 1901 Respectfully submitted

JOHN M. CLARKE

State paleontologist

Plate 1


IN THIS HOUSE, THE HOME OF
DR. EBENEZER EMMONS
THE FIRST FORMAL EFFORTS WERE MADE, IN
1838 AND 1839, TOWARD THE ORGANIZATION OF THE
ASSOCIATION OF AMERICAN GEOLOGISTS
THE PARENT BODY OF THE
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1901

George Bancroft Simpson

1844-1901

George B. Simpson was born at Boston Mass. Nov. 1, 1844. His father was a mechanical genius and inventor and, though not fortunate in the affairs of this world, was a high-minded man, of upright life and a pillar of the methodist church. His mother was a woman of strong character, genial and lovable disposition. She was the sister of the late Prof. James Hall. Mr Simpson in his young manhood apprenticed himself to a printer, but soon after the breaking out of the civil war, he enlisted for the service, enrolling with Company F, 68th Illinois volunteers, on the 5th of June, 1862. He served with his company for the full term of his enlistment, turning in his bounty and pay to the support of the home, which had then been moved to Waterbury Ct. After his first discharge he came to Albany and was for a brief time employed by Prof. Hall as a collector of fossils, but he soon reenlisted, this time volunteering with the 106th New York infantry, and served therewith till the end of the war. He then entered Yale college, having an ambition for the law, but financial misfortunes fell on the home and were closely followed by the death of the father, so that the cherished hope had to be abandoned, and the young man left college to seek his own and his mother's fortune and to maintain the homestead at Waterbury. He turned to his uncle in Albany, and then, 1868, at the suggestion of Prof. Hall and under the tutelage of the artists who were employed on the paleontologic work of the state, Mr F. H. Swinton and Prof. R. P. Whitfield, he undertook the drawing of fossils for these publications. Here he remained till his death, except for an absence of two years in Pennsylvania, when he was engaged on similar work for the second geological survey of that state.

Mr Simpson's nature was sensitive and retiring, and he was more inclined to shun than seek companionship, so that very few saw the true spirit of the man or realized the motive of his life. Such men, failing to enforce a recognition of their real

merits, pass through life with less than their deserts from their fellows. One whose association with him for many years was close enough to permit him to see within this veil, feels a conviction that the root of every endeavor in this life toward the best ideals, the best execution in daily work, was the love for his mother. In her seemed to be centered all his desire for companionship, for laudation and approval, and for her and the home at Waterbury he provided to the end of her life. From this excellent woman and his good father he seemed to have inherited many fine traits of character, a strict integrity and conscientious punctiliousness and perhaps also his delight in nature and all her works. In his work of preparing scientific drawings of paleontologic objects he succeeded for accuracy of expression and of detail far beyond his own expectation, attaining a power that few have equaled. The thousands of drawings which he made for the *Paleontology of New York* contributed in a most important way to the value and prestige of that work. Less can not be said than that he was the vehicle for the proper expression of our paleontologic data; and many a working paleontologist has allowed himself to express the feeling that a publication, specially of a descriptive character, is less serviceable without the illustrations than the illustrations without the description. On looking at some of his most skilful and elaborate drawings of crustaceans and plants from the Coal Measures, Prof. Lesley, the former state geologist of Pennsylvania, expressed his amazement that such execution was within human power; and yet but few saw the results of Mr Simpson's handiwork save after they had passed through the printing press and were shorn of their finer beauties. Mr Simpson was draftsman less of choice than of necessity. Had his way been clear before him and the preliminary training attainable, his deep seated, never lessening love of nature would have carried him to successful accomplishment in some branch of natural history. The flowers were his constant companions; he seemed to crave their unspoken sympathy, and knew and loved their haunts. When he painted them, it was with a preraphaelite touch that was startling in the exactitude of detail.

This interest in natural history expressed itself in other ways and in much more serious and substantial manner in his published demonstrations of the anatomy of the fresh-water clam (*Anatomy and physiology of Anodonta fluviatilis,* 35th rep't N. Y. state mus. 1884. p. 169-91, pl. 1-11) and in a beautiful and still more elaborate memoir on the anatomy of the snails (*Anatomy and physiology of Polygyra albolabris and Limax maximus and embryology of Limax maximus,* N. Y. state mus. bul. 40) which he did not live to see in published form, but of which almost his last conscious act was to read the proof sheets. One naturally turns first to the illustrations of these papers; and it is worthy of remark that the drawings of this memoir on the snails are the most highly finished that ever came from its author's hands. They were marvels of handiwork and have elicited unstinted praise from expert students of the Mollusca. They have proved, however, beyond the capacity of the printers to reproduce and have hence lost much of their beauty. These works demonstrated Mr Simpson's natural taste for scientific investigation.

In the execution of the various volumes on the *Paleontology of New York,* Prof. Hall planned one on the Bryozoa, a group of lowly molluscoid organisms which abounded in profusion in the old faunas of New York. The drawing of these organisms required great skill and much study, and it naturally followed that the draftsman acquired a close familiarity with this multitude of specific forms, their variations and mutual relations. He became in fact more familiar with them than any one else could become without long and laborious study; and as a consequence Mr Simpson was the virtual author of vol. 6 of the *Paleontology of New York,* which was almost exclusively concerned with these organisms, and not only of this but of all the descriptive matter pertaining to these fossils published during the decade from 1880 to 1890. One outcome of this work was the *Handbook of North American Paleozoic Bryozoa,* published by Mr Simpson, the usefulness of which to many students can not be gainsaid. All these publications on the Bryozoa were substantial contributions to the paleontology of the ancient rocks,

though in certain directions they have been the subject of a criticism whose very rawness has deprived it of force.

The study of the Bryozoa happened, in the plans of Prof. Hall, to be involved with that of the corals; and, as Mr Simpson was called on to make the necessary drawings of these organisms also, and again the execution of the work was dependent on the correct representation of fine internal, structural characters, the artist acquired a detailed knowledge also of these obscure characters. Mr Simpson supplied all descriptive matter pertaining to the corals published from 1880 to 1890. For some time before the death of Prof. Hall material was being gathered and studied for a more comprehensive memoir on the genera and species of the extinct corals; and on the drawings and descriptive part of this work Mr Simpson labored faithfully to within a few months of his death. Thus in this field too we shall find ourselves owing much to his fine powers of observation.

Mr Simpson married in 1891 Miss Abigail L. Soule, who survives him.

J. M. C.

APPENDIX 1

ACCESSIONS

The additions to the paleontologic collections have been by donation, purchase, exchange and collection. A detailed statement of these acquisitions is given herewith.

Donations

Judson, W. P., Albany

Trilobite from the Trenton limestone, Chaumont.	1	
Fossils from the Onondaga limestone, bottom of Lake Erie.	2	

Luther, D. D., Naples

Triarthrus from the Utica slate near Rome.	50	

Walcott, C. D., U. S. national museum

Specimens of Beltina danai Walc. Belt series (pre-Cambric) Glenwood and Neihart Mont.	25	

Derby, O. A., Sao Paulo, Brazil

Notothyris ? smithi Derby. Middle Devonic, Matto Grosso, Brazil.	3	

Bennett, L. J., Buffalo

Pterygotus and Eurypterus. Waterlime, Buffalo.	3	

Wilson, J. D., Syracuse

Thoracoceras wilsoni Clarke. Agoniatites limestone, Manlius.	4	(4 types)

Swartz, C. K., Bellevue O.

Fossils from Onondaga limestone. Stafford.	2	

Loomis, F. B., Amherst Mass.

Fossils from Clinton limestone:

Peronosporites ramosus Loomis P. globosus Loomis P. minutus Loomis	4	(4 types)

Calvin, Samuel, Iowa City Ia.
Devonic fossils, Lime Creek and Independence Ia. 150

Letson, Elizabeth J., Buffalo
Pleistocene shells from Niagara river, illustrated in museum bulletin 45. 40 (33 hypotypes)

Dolph, J. M., Port Jervis
Pleurotomaria sulcomarginata var. Hamilton beds, Port Jervis. 1

The paleontologist
A collection of fossils from various New York localities of the Helderberg and Onondaga limestones, the Marcellus shales, Hamilton, Genesee, Naples, Oneonta and Chemung beds; together with specimens of minerals (200) and Indian relics (450). 5 296

This collection includes the following type specimens:

Crustacea (Hamilton)	3
Goniatites (Genesee and Naples)	125
Lamellibranchs (Genesee and Naples)	116
Miscellaneous (Naples)	6
Miscellaneous (Genesee)	18
	268

Hall, E. B., Wellsville
Chemung fossils from Broome co. 40

Davis, E. E., Norwich
Fossils from the Ithaca formation near Norwich and Coventry. 15
Psaronius. Large specimen from Oneonta sandstone, Oxford. 1

Chadwick, G. H., Catskill
Paropsonema cryptophya, from Naples beds, Hicks's gully, Canandaigua lake. 1

Fossils from Oneonta shales near Lawrence station, Greene co.	10	
Wood, Elvira, Waltham Mass.		
Fossils from the Stafford limestone, Lancaster, Erie co.		
Carnia recta Wood	1	(1 type)
Ambocoelia nana ? Grabau	1	(1 type)
Gordon, Robert H., Cumberland Md.		
Goniatites from the Marcellus shales at Cumberland and Corrigansville Md.	17	
Clark, W. B.,		
Fossils from the Jennings formation, western Maryland.	1bbl.	
Total by donation	5 667+1bbl.	(278 types; 33 hypotypes)

Purchases

The **S. W. Ford** collection of Cambric fossils:		
Palaeophycus incipiens Bill., Troy	2	
Archaeocyathus rarus Ford, Troy	1	(1 type)
A. rensselaericus Ford, Troy	1	(1 type)
Ethmophyllum ? (cast), Troy	1	
Lingulella caelata Hall, Troy	36	(3 hypotypes)
Obolella crassa Hall, Troy	46	(6 hypotypes)
Obolella crassa Hall, Lansingburg	1	
O. gemma Bill., Troy	6	(3 hypotypes)
O. nitida Ford, Troy (6 specimens missing)		
O. nitida ? Ford, Lansingburg	1	
Kutorgina labradorica Bill., Swanton Vt.	7	(4 hypotypes)

Billingsella festinata Bill., Swanton Vt.	1	
Scenella retusa Ford, Troy	1	(1 type)
Stenotheca rugosa Hall, Troy	9	
Stenotheca rugosa Hall, Lansingburg	1	
Hyolithus (sp.), Troy	1	
H. americanus Bill., Troy	29	
H. communis var. emmonsi Ford, Troy	14	(2 types)
H. impar Ford, Troy	15	(3 types)
H. micans Bill., Troy	38	
Fordilla troyensis Barr., Troy	5	(5 hypotypes)
Aristozoe troyensis Ford, Troy	1	(1 type)
Bathyurus senectus Bill., Bic harbor Can.	2	
Microdiscus speciosus Ford, Troy	60	(3 types)
Microdiscus speciosus Ford, Lansingburg	1	
M. meeki Ford, Troy	1	(1 type)
M. lobatus Hall, Troy	7	
M. punctatus ? Salter, St John N. B.	1	
M. (sp.), Bic Harbor Can.	2	
Olenellus asaphoides Em., Troy	80	(12 hypotypes)
O. asaphoides Em., Bald mountain	3	
O. asaphoides Em., Lansingburg	5	
O. vermontana Hall, Parker's farm, Vt.	1	
O. thompsoni Hall, L'Anse-au-Loup Can.	1	
Ptychoparia teucer Bill., ½ mile east of Swanton Vt.	1	

P. *teucer* Bill., Highgate Vt.	1	
P. *saratogensis* Walc., Poughkeepsie	4	
Conocoryphe trilineata Em., Reynold's Inn, Washington co.	1	(1 plastotype)
Conocoryphe trilineata Em., Troy	17	(2 hypotypes)
Solenopleura nana Ford, Troy	10	(1 type)
Solenopleura nana Ford, Lansingburg	1	(1 hypotype)
(Missing, specimens of *Obolella nitida* Ford, including 1 type and type of *Agnostus nobilis* Ford, reported lost by Mr Ford)		
Total specimens 416		
types 14		
hypotypes 36		
plastotypes 1		
Ward & Co., Rochester		
Trenton fossils	4	
Waterlime fossils	1	
Camarocrinus, Helderbergian Cumberland Md.	5	
Total by purchase	426	(14 types; 36 hypotypes)

Exchanges

Crandall, A. R., Alfred		
Pephricaris horripilata Clarke.	1	(1 type)
Cincinnati society natural history, through Dr Josua Lindahl		
Phragmodictya catilliformis. Keokuk beds, Crawfordsville Ind.	1	

Judson, W. P., Albany

Amphigenia elongata. Bottom of Lake Erie at Buffalo.	1	

Cushing, H. P., Cleveland O.

Type specimens from the collection of Prof. S. G. Williams deceased, formerly of Cornell university, Ithaca:

Nautilus (Discites) inopinatus Hall. Onondaga limestone, Kelleys Island O.	1	(1 type)
Orthoceras caelamon Hall. Hamilton shales, Moravia	2	(2 types)
O. lima Hall. Hamilton shales, Cazenovia	1	(1 type)
Gomphoceras pingue Hall. Hamilton shales, north of Cazenovia	1	(1 type)
Orthoceras pertextum Hall. Ithaca beds, Cornell-Fiske quarry, Ithaca	1	(1 type)
O. bebryx var. cayuga Hall. Ithaca beds, Earl's quarry, Ithaca	2	(2 types)
O. bebryx var. cayuga Hall. Ithaca beds, University quarry, Ithaca	4	(4 types)
O. bebryx var. cayuga, Cascadilla ravine, Ithaca	1	(1 type)
Manticoceras sinuosus Hall. Ithaca beds, University quarry, Ithaca	2	(2 hypotypes)
Orthoceras anguis Hall. Ithaca beds, Cascadilla creek, Ithaca	3	(1 type)
O. fulgidum Hall. Ithaca beds, Cascadilla creek, Ithaca	1	(1 type)

O. demus Hall. Ithaca beds, Cascadilla quarry, Ithaca	1	(1 type)
Gomphoceras tumidum Hall. Ithaca beds, Cascadilla quarry, Ithaca	1	(1 type)
Totai by exchange	24	(18 types; 2 hypotypes)

The paleontologist	Collections
Crustacea from the black shales at base of the Salina, 1½ miles northwest of Pittsford	19
The paleontologist and Luther, D. D.	
Fossils from the Guelph dolomites at Galt, Hespeler and Elora Ont.	225
Ruedemann, Rudolf	
Graptolites from the Beekmantown horizon, Melrose	1 420+1bbl.
Fossils from the Agoniatite limestone, Cox's ravine, Cherry Valley	100
Luther, D. D.	
Fossils from the Ithaca beds, Killawog, Lisle and vicinity	300
Crustaceans from the Waterlime beds at Wheelock's farm, Litchfield	90
Fossils from the upper Ithaca and Chemung rocks, Greene	70
Fossils from the Portage rocks of Naples and the Salina shales near Pittsford	75
Guelph fossils from canal feeder, 2 miles south of Shelby	60
Laforge, Laurence	
Niagara fossils from Middleport	300
Butts, Charles	
Remainder of fossils from the Chemung and Carbonic rocks of Olean sheet, 1900	2 400

Fossils from the higher Devonic and lower Carbonic strata at localities situated on the Salamanca topographic sheet	800
Hartnagel, C. A. and Mattimore, H. S.	
Ithaca fossils from sections in Tompkins co.	1 140
van Ingen, Gilbert	
Fossils from the Potsdam and Beekmantown horizons in the Lake Champlain basin	400
Grabau, A. W.	
Fossils from limestone lenses in the Clinton formation at Middleport and Gasport	300
Van Deloo, Jacob	
Euomphalus from the Chemung sandstone near Union, Broome co.	13
Total by collection	7 712+1bbl.
Total accessions	13 829+2bbl. (310 types; 71 hypotypes)

APPENDIX 2

NEW ENTRIES ON GENERAL RECORD OF LOCALITIES OF AMERICAN PALEOZOIC FOSSILS BELONGING TO STATE MUSEUM

ALPHABETIC LIST OF LOCALITIES

Albany (North Albany), (Albany co.), 2565

Alfred (Allegany co.), 2931

Allegany (Cattaraugus co.), 2697, 2700, 2702, 2706, 2708, 2713, 2720, 2723, 2724, 2727, 2728, 2733, 2865

Allen creek (Monroe co.), 3047, 3051

Asbury (Tompkins co.), 2958, 2959

Ausable chasm (Clinton co.), 3031, 3032, 3033, 3034, 3035, 3036, 3037, 3038, 3039, 3040, 3041, 3042, 3045

Avoca (Steuben co.), 2932

NEW YORK LOCALITIES ACCORDING TO COUNTIES

(Names in italic are new to the record.)

Albany co.
- Albany
- *North Albany*

Allegany co.
- Alfred
- Belmont
- Belvidere
- *Bowler station*
- *Ceres*
- *Clarksville*
- *Clarksville Center*
- *Coon hollow*
- *Cuba*
- *Deer creek*
- *Dodge creek*
- Friendship
- Little Genesee
- *North Cuba*
- *Van Campens creek*
- Wellsville
- *Windfall creek*
- *Wolf creek*

Broome co.
- *Kirkwood*
- *Ouaquaga*
- *Tracy Creek*
- *Union*

Cattaraugus co.

Allegany
Barker run
Beehive creek
Bennetts hollow
Birch run
Boardman
Bolivar creek
Bova creek
Bozard hill
Carroll
Carrollton
Cary hollow
Chapin hill
Chipmunk creek
Coopers hill
Dodge creek
Dutch hill
Ellicottville
Fay hollow
Five Mile creek
Four Mile creek
Great Valley
Great Valley creek
Gull brook
Halls
Harrisburg
Haskell creek
Haskell Flats
Hinsdale
Humphrey Center
Hungry hollow
Irish brook
Irvine Mills
Ischua
Ischua creek

Cattaraugus co. (*continued*)

Killbuck
Knapp Creek
Learn hill
Limestone
Limestone brook
Little Valley
Louds creek
McIntosh creek
Mount Hermon
Mount Moriah
Mutton hollow
Newton run
Nine Mile creek
Oil creek
Olean
Oswayo creek
Peth
Portville
Pumpkin hollow
Red House creek
Rice brook
Riverside junction
Rock City
Russell station
Salamanca
Scott
Sugartown
Tuna creek
Tuna Valley
Two Mile creek
Vandalia
Wayman branch
Westons Mills
Wildcat creek
Wildcat hollow

Cattaraugus co. *(continued)*
- *Wing hollow*
- Wolf run
- *Woodchuck hollow*

Cayuga co.
- *Hollow brook*
- *Locke*
- Moravia

Chemung co.
- Elmira

Chenango co.
- Burdick
- *Cowles hill*
- *Flagg gulf*
- Greene
- Juliand hill
- Oxford
- Pitcher mineral springs ravine
- South Otselic
- *West [Willard's] hill*

Clinton co.
- Ausable chasm
- Beekmantown station
- *Champlain*
- Chazy
- *Coopersville*
- *Corbeau creek*
- *Day point*
- *Kent's falls*
- *Laphams Mills*
- *Mooers*
- Plattsburg
- *Schuyler Falls*
- *South Plattsburg*

Clinton co. *(continued)*
- Valcour station
- *West Chazy*

Columbia co.
- Becraft mountain

Dutchess co.
- *Poughkeepsie*

Erie co.
- Buffalo
- Fox's point
- Pontiac
- *Stony point*
- *West Seneca*

Essex co.
- *Burdick's crossing*
- *Crown Point*
- *Flat Rock point*
- *Port Kent*
- *Ticonderoga*
- *Ticonderoga creek*
- *Willsboro*

Franklin co.
- *Chateaugay*

Genesee co.
- Stafford

Greene co.
- *Camp Heart's Content*
- *Lawrence station*

Herkimer co.
- *Dolgeville*
- Litchfield

Livingston co.
- Cashaqua creek
- Dansville
- Mount Morris

Madison co.
- Cazenovia
- *De Ruyter*

Monroe co.
- *Allen creek*
- *Pittsford*

Niagara co.
- Lockport

Oneida co.
- Trenton Falls

Onondaga co.
- Manlius
- Spafford

Ontario co.
- Bell's gully
- Bristol Center
- Canandaigua
- Centerfield
- *Cummings crossing*
- Flint creek
- Geneva
- Grimes gully (Naples)
- *Gull berg*
- *Hatch hill*
- High point
- *Knapp hill*
- *Lincoln gully*
- Naples
- Parrish gully
- West hill
- *Woodville*

Orleans co.
- *Shelby*

Otsego co.
- Cherry Valley
- *Cox's ravine*

Otsego co. (*continued*)
- Emmons
- Laurens
- New Lisbon [Noblesville

Rensselaer co.
- *Bald mountain*
- *Grant Hollow*
- Lansingburg
- *Melrose*
- Troy

Schoharie co.
- Schoharie

Schuyler co.
- *Havana glen*

Seneca co.
- *Lodi falls*

Steuben co.
- Avoca
- Prattsburg

Tompkins co.
- *Asbury*
- *Buttermilk falls*
- Cascadilla creek
- *Esty glen*
- *Fall creek*
- *Forest Home*
- *Glenwood*
- *Groton*
- Ithaca
- *Ithaca falls*
- Ludlowville
- *McKinney's*
- *Peruville*
- *Portland*
- *Renwick creek*
- *Salmon creek*

INDEX TO FORMATIONS

2831, 2832, 2834, 2835, 2836, 2838, 2840, 2841, 2847, 2853, 2860, 2862, 2865, 2875, 2880, 2894, 2895, 2897, 2898, 2899, 2900, 3058, 3059, 3067, 3068, 3071, 3073, 3074, 3075, 3077, 3079, 3080, 3086.

Coal Measures, 2580.

RECORD OF LOCALITIES

2526 Ithaca beds; upper layers. Quarry on hillside north of Emmons, Otsego co. D. D. Luther, collector. 1900.

2527 Ithaca beds. Cowles hill, Greene, Chenango co. D. D. Luther, collector. 1900.

2528 Ithaca beds. West, or Willard's, hill, ¼ mile west of Greene, and ¼ mile north of Cowles hill. D. D. Luther, collector. 1900.

2529 Chemung beds. Flagg gulf, lower part, Greene. D. D. Luther, collector. 1900.

2530 Ithaca beds. Juliand hill, Greene. D. D. Luther, collector. 1900.

2531 Tully horizon. Laurens, Otsego co.; small ravine west of village. D. D. Luther, collector. 1900.

2532 Tully horizon. 1 mile southwest of New Lisbon [Noblesville], Otsego co. D. D. Luther, collector. 1900.

2533 Ithaca beds. Loose near top of hill southeast of De Ruyter, Madison co. C. S. Prosser, collector. (1895) 1901.

2534 Ithaca beds. 3 miles east of South Otselic, Chenango co., and in glen below the "upper reservoir"; Priest's farm. C. S. Prosser, collector. (1895) 1901.

2535 Ithaca beds (Sherburne). In glen southeast of De Ruyter. C. S. Prosser, collector. (1895) 1901.

2536 Ithaca beds. Lower part of glen east of South Otselic. C. S. Prosser, collector. (1895) 1901.

2537 Ithaca beds. Loose in Havana glen, Schuyler co. C. S. Prosser, collector. (1895) 1901.

2538 Ithaca beds. Shales in lower part of glen east of South Otselic. C. S. Prosser, collector. (1895) 1901.

2539 Ithaca beds. Glen east of South Otselic; above the "lower reservoir." C. S. Prosser, collector. (1895) 1901.

2540 Ithaca beds. Burdick quarry on hill 1½ miles southeast of De Ruyter and 324 feet above the village. C. S. Prosser, collector. (1895) 1901.

2541 Ithaca beds. Lower part of Pitcher mineral springs ravine, Chenango co. C. S. Prosser, collector. (1895) 1901.

2542 Ithaca beds. Shaly sandstone and shales with base of North Norwich fauna, in glen east of South Otselic. C. S. Prosser, collector. (1895) 1901.

2543 Ithaca beds. In glen east of South Otselic from roadside below the "lower reservoir." C. S. Prosser, collector. (1895) 1901.

2544 Ithaca beds. Glen east of South Otselic; Tropidoleptus zone at second bridge. C. S. Prosser, collector. (1895) 1901.

2545 Ithaca beds. On roadside east of Burdick, Chenango co.; Portage barren shales with part of the Sp. mucronatus (Ithaca) fauna. C. S. Prosser, collector. (1895) 1901.

2546 Ithaca beds. Glen east of South Otselic; above Tropidoleptus zone. C. S. Prosser, collector. (1895) 1901.

2547 Ithaca beds. Driscoll's quarry east of State st., Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2548 Ithaca beds. South Cayuga st., Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2549 Ithaca beds. Fowler's quarry south of Ithaca along Delaware, Lackawanna and Western railroad, just beyond 2550. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2550 Ithaca beds. Sheehy's quarry, Ithaca; first quarry south of Ithaca along Delaware, Lackawanna and Western railroad. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2551 Ithaca beds. Foot of Buttermilk falls, Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2552 Ithaca beds. Reservoir above Buttermilk falls, Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2553 Ithaca beds. Peruville, Tompkins co.; in creek bed and sides of creek just below village. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2554 Ithaca beds. Just below street railway bridge, Cornell hights, Ithaca; horizon slightly higher than 2976. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2555 Ithaca beds. Foot of Triphammer falls, Fall creek, Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2556 Ithaca beds. Bates quarry along Delaware, Lackawanna and Western railroad tracks on hill south of Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2557 Ithaca beds. Glenwood, Tompkins co.; along creek ¾ mile from Cayuga lake. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2558 Ithaca beds. Below mill dam, Forest Home, Tompkins co. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2559 Lower Portage beds. 1 mile below Esty glen, Cayuga lake (Tompkins co.), along railroad. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2560 Ithaca beds. South glen at McKinney's, Cayuga lake, 50 yards above 2956. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2561 Ithaca beds. North glen at McKinney's, Cayuga lake; 20 feet above lake. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2562 Ithaca beds. North glen at McKinney's, Cayuga lake; second falls, 130 feet above lake. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2563 Ithaca beds. North glen at McKinney's, Cayuga lake; short distance above 2955. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2564 Ithaca beds. South glen at McKinney's, Cayuga lake, 50 yards above 2960. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2565 Utica horizon. Felt mill, city line (North Albany) Albany. H. S. Mattimore, collector. 1901.

2566 Genesee shale. Right branch of Salmon creek, 2¼ miles northeast of Ludlowville, Tompkins co. 540 feet A. T.

2567 Onondaga limestone. Stafford, Genesee co. C. K. Swartz, donor.

2568 Onondaga limestone. Bottom of Lake Erie at Buffalo. W. P. Judson, donor. 1901.

2569 Onondaga limestone. Kelleys Island O. H. P. Cushing, Cleveland O., exchange. 1901.

2570 Hamilton beds. Moravia, Cayuga co. H. P. Cushing, exchange. 1901.

2571 Hamilton beds. Cazenovia, Madison co. H. P. Cushing, exchange. 1901.

2572 Ithaca beds. Cornell-Fiske quarry, Ithaca. H. P. Cushing, exchange. 1901.

2573 Ithaca beds. Earl's quarry, Ithaca. H. P. Cushing, exchange. 1901.

2574 Ithaca beds. University quarry, Ithaca. H. P. Cushing, exchange. 1901.

2575 Ithaca beds. Cascadilla creek, Ithaca. H. P. Cushing, exchange. 1901.

2576 Ithaca beds. Cascadilla quarry, Ithaca. H. P. Cushing, exchange. 1901.

2577 Waterlime; Eurypterus beds. Buffalo cement co.'s quarry, Buffalo. L. J. Bennett, donor. 1901.

2578 Trenton limestone. Trenton Falls, Oneida co. Ward & Howell purchase. 1901.

2579 Waterlime; Eurypterus beds. Litchfield, Herkimer co. Ward & Howell purchase. 1901.

2580 Lower barren Coal Measures. Carrolton O. J. M. Clarke, donor. 1900.

2581 Algonkian (Belt terrane); Greyson shales. Beltina danai Walc. Near Glenwood and Neihart Mont. U. S. national museum, through C. D. Walcott, donor. 1900.

2582 Ithaca beds; lower strata. Quarry on land of David Wilcox, 225 feet above Tully limestone; ¼ mile south of cemetery, De Ruyter, Madison co. J. M. Clarke, collector. 1895.

2583 Waterlime. Litchfield, Herkimer co.; small outcrop on Alger farm next east of the Wheelock farm. D. D. Luther, collector. 1900.

2584 Helderbergian. Herkimer co. Ward & Howell purchase. 1900.

2585 Niagara limestone. Lockport, Niagara co. Ward & Howell purchase. 1900.

2586 Cambric. Troy, Rensselaer co. S. W. Ford collection, purchased. 1900.

2587 Cambric. Lansingburg, Rensselaer co. S. W. Ford collection, purchased. 1900.

2588 Cambric. Bald mountain, near Lansingburg. S. W. Ford collection, purchased. 1900.

2589 Cambric. Reynold's Inn, Washington co. S. W. Ford collection, purchased. 1900.

2590 Cambric. Poughkeepsie. S. W. Ford collection, purchased. 1900.

2591 Cambric. Near Swanton Vt. S. W. Ford collection, purchased. 1900.

2592 Cambric. Bic Harbor Can. S. W. Ford collection, purchased. 1900.

2593 Cambric. St John N. B. S. W. Ford collection, purchased. 1900.

2594 Cambric. Highgate Vt. S. W. Ford collection, purchased. 1900.

2595 Cambric. Parker's farm Vt. S. W. Ford collection, purchased. 1900.

2596 Cambric. L'Anse-au-Loup Can. S. W. Ford collection, purchased. 1900.

2693 Marcellus (Agoniatite) limestone. Manlius, Onondaga co. John D. Wilson, Syracuse, donor.

2694 Upper Devonic. Hackberry Grove, Lime Creek Ia. Samuel Calvin, donor. 1901.

2695 Upper Devonic. Independence Ia. Samuel Calvin, donor. 1901.

2696 Oriskany beds. Becraft mountain, Columbia co. J. M. Clarke, C. E. Beecher, C. Schuchert and M. Sheehy, collectors.

Fossils collected by Charles Butts in area covered by the Olean quadrangle, Cattaraugus county, 1900. The horizons of this area are numbered as follows, beginning at the top. Locality numbers 2697-2863 inclusive.

1	Arenaceous shales above the Olean conglomerate	15 feet
2	Olean conglomerate	60 feet
3	Interbedded shales and sandstones with Camarotoechia allegania Williams	150 feet
4	Impure limestone	4-5 feet
5	Barren shales and sandstones	100 feet
6	Mount Hermon sandstones	10 feet
7	Interbedded red and green shales and flaggy and shaly arenaceous sandstones	220 feet
8	Wolf creek conglomerate	10 feet
9	Green shales and thin bedded arenaceous sandstones	130 feet
10	Chocolate shales and purplish sandstones; upper limit of Athyris angelica	100 feet
11	Shales and sandstones	75 feet
12	Shales and arenaceous sandstones with abundance of Orthothetes chemungensis	160 feet
13	Cuba sandstone	10–15 feet

Thicknesses as here given are only approximate. Numbers referring to these horizons are recorded with the following entries:

2697 Ravine south from near head of Cary hollow, 2 miles southwest of Allegany, Cattaraugus co. 1675 feet and

1780 feet A. T., no. 9; 1840 feet and 1950 feet A. T. (loose), no. 6 or 8.

2698 Ravine northwest of road between Four Mile and Chipmunk creeks, 1½–3 miles southwest of Allegany. 1700 feet A. T., no. 6.

2699 Northwest side of high hill 1 mile south of road between Four Mile and Chipmunk creeks. 2050 feet A. T. (loose), no. 3.

2700 South side of high hill 4 to 5 miles southwest of Allegany. 2100 feet A. T., no. 3.

2701 Loose near top of hill ¼ mile north of Knapp Creek. 2270–2330 feet A. T., no. 3.

2702 Road just east of Knapp Creek and road from Knapp Creek down Four Mile creek to Allegany. [A 89] 2330 feet A. T., no. 3; [A 90] 2300 feet A. T., no. 3; 2150 feet and 2130 feet A. T., no. 4; 1850 feet A. T., no. 7; 1850 feet A. T. horizon?

2703 Old, washed-out road south of Rock City and just north of New York-Pennsylvania boundary. 1830 feet A. T., no. 7; 1820 feet A. T., no. 7.

2704 Loose; cut from layer of shale in place at summit above conglomerate at Rock City, southwest of Olean. 2360 feet A. T., no. 3.

2705 Old quarry on road between Olean and Five Mile creek, 2 miles northwest of Olean. 1590 feet A. T., no. 10.

2706 Pit on top of hill ¾ mile east of junction of Five Mile, Allegany and Olean roads. 1810 feet A. T., no. 9.

2707 South of Wing hollow, 1 mile west of Five Mile road, Allegany township. 2000 feet A. T. (loose), no. 6.

2708 Eastern spur of high hill at head of Wing hollow, 4 miles northwest of Allegany. 1960 feet and 1710 feet A. T. (loose), no. 6.

2709 Cut in Olean, Rock City and Bradford trolley line, about 2 miles southwest of Olean. 1640 feet A. T., no. 10.

2710 Eastern spur of high hill at head of Wing hollow in angle between Wing hollow and Five Mile road. 1800 feet A. T., no. 9.

2711 Blind road near Olean-Allegany township boundary, 3 miles northwest of Olean. 1880 feet and 1910 feet A. T., no. 9.

2712 Top of ridge between Olean and Bennett's hollow near Olean-Allegany township boundary, 3 miles northwest of Olean. 1930 feet and 2030 feet A. T. (loose), 1965 feet A. T., no. 8.

2713 Near head of southeast branch of Birch run, southwest of Allegany. 1840 feet, 2015–25 feet A. T. (loose), no. 6.

2714 On hillside above trolley road, 2½ miles southwest of Olean. 1600 feet A. T. (loose), no. 9?

2715 ¼ mile east of Erie R. R. depot, Vandalia. 1440 feet A. T., no. 12.

2716 State line by Olean, Rock City and Bradford trolley road. 2300 feet A. T., no. 3.

2717 Loose; trolley road about 4 miles southwest of Olean. 1760–1800 feet A. T., no. 8.

2718 Crest of ridge between Two Mile and Four Mile creeks, about 4 miles southwest of Olean. 1890 feet A. T., no. 7.

2719 Cut on Olean, Rock City and Bradford trolley road between state line and Knapp Creek. 2315 feet A. T., no. 3.

2720 South of road between Four Mile and Chipmunk creeks, 3½ miles southwest of Allegany. 1770 feet A. T., no. 9.

2721 Along Four Mile creek about 4 miles southwest of Olean. 1560 feet A. T., no. 9.

2722 West side of northwest spur of Rock City hill. 1985 feet A. T., no. 6.

2723 Four Mile road near where road to Rock City branches off, 4–5 miles south of Allegany. 1725 feet A. T., no. 9.

2724 Road between Nine Mile and Five Mile creeks, about 5½ miles northwest of Allegany. 1685 feet A. T., no. 11.

2725 1–2 miles northeast of Harrisburg, 3 miles north of New York-Pennsylvania boundary line. 2320 feet A. T., no. 3.

2726 Pumpkin hollow road, $\frac{3}{4}$, 1, $1\frac{1}{2}$ miles west of Five Mile road, [A 247] 1630 feet A. T., no. 11, [A 247[1]] 1760–1800 feet A. T., no. 10, [A 247[2]] 1760 feet A. T. (loose), no. 6.

2727 Road over Chapin hill near Allegany-Humphrey boundary about 5–6 miles north of Allegany. 1720 feet A. T., no. 11.

2728 Road over Chapin hill just north of Allegany-Humphrey boundary about 5 miles north of Allegany. [A 248[2]] 1800 feet A. T., [A 248[4]] 1880 feet A. T., no. 10.

2729 Summit of northeastern spur of Mt Moriah, about 1 mile south of Russell station, Pennsylvania R. R. [A 251[1-3]] 1630 feet A. T., no. 9, [A 251[4]] 1940 feet A. T., no. 7.

2730 West side of Mt Moriah $\frac{1}{2}$ mile south of Russell station on Pennsylvania R. R. 2140 feet A. T., (loose) horizon? [A 252] 2140 feet A. T. loose? [A 252[1]] 2120 feet A. T., no. 6.

2731 West side of Mt Moriah. [A 252[2]] 2060 feet A. T., no. 7, [A 252[3]] 2030 feet A. T., no. 7.

2732 Road forking at state line south of Knapp Creek. 2300 feet A. T. (loose), no. 3.

2733 End of blind road $3\frac{1}{2}$ miles northwest of Allegany. [A 257] 1850 feet A. T. (loose), no. 9,? [A 258[&1]] 2000–1860 feet A. T. (loose), no. 9?

2734 Bed of Van Campen's creek just above railroad bridge, Belvidere, Amity township, Allegany co. 1400 feet A. T. Below Cuba sandstone.

2735 Quarry near Belmont cemetery; loose stone on roadside $\frac{1}{2}$ mile southwest of Belmont. 1470 feet A. T. Below Cuba sandstone.

2736 West of Glenn postoffice, McKean co. Pa. at 2190 feet; road forking. 2100–2190 feet A. T., no. 4?

2737 Ravine 1 mile southwest of Clarksville, Allegany co. west of highway. 1650–1700 feet A. T., no. 12.

2738 Loose near head of ravine on east side of highway about $\frac{1}{4}$ mile south of Clarksville Center, Allegany co. [Cl. 21] 1650–1800 feet A. T. [Cl. 22] 1770–1795 feet A. T., no. 12.

2739 Loose at head of ravine on east side of highway about ⅓ mile south of Clarksville Center. 2000 feet A. T., no. 7?

2740 Loose east side of Wolf creek near Joel Wixon's farm about 6 miles northeast of Portville. 1800 feet A. T., no. 8. Collection from boulders horizon of conglomerate 50–75 feet higher.

2741 Loose on hillside east of Wolf creek about 1½ miles north of junction with Dodge's creek. 1950 feet A. T., no. 7.

2742 Road ditch near head of Wolf run. 2160 feet A. T., no. 7.

2743 Ravine on hillside ½ mile due north of Clarksville Center. 1710 feet A. T., no. 9.

2744 West side of Wolf creek, steep escarpment west of wide flat in valley bottom 5 miles northeast of Portville. 1890 feet and 1895 feet A. T., no. 8; 2225 feet A. T., no. 3.

2745 Road on Wolf creek about 7 miles northeast of Portville. 1875 feet A. T. (loose), horizon?

2746 Summit of hill, given as 2378 feet on Olean quadrangle, between Wolf creek and Wolf run. 2360 feet A. T., no. 3.

2747 Summit on Cuba-Clarksville road, Clarksville township. 2050 feet A. T. (loose), no. 8.

2748 Roadside cut Cuba-Clarksville road in Clarksville township; also loose on summit of road. 1850 feet A. T., no. 9.

2749 Southwestern part of Clarksville township. 2000 feet A. T., no. 8.

2750 Top of hill about 4 miles nearly due south of Cuba and just south of Cuba-Clarksville boundary. 2122 feet A. T., no. 7.

2751 Bank of creek on Cuba-Clarksville road near third road forking south of Cuba. 2020 feet A. T. (loose), no. 8?

2752 Ravine east of Cuba-Haskell road just south of Cuba-Clarksville boundary. [Cl. 160] and [Cl. 160^2] 1710 feet and 1795 feet A. T., no. 11; [Cl. 160^3] ?, [Cl. 160^{4-8}] 1810-60 feet A. T., no. 10.

2753 Roadside 1 mile south of Cuba-Clarksville boundary. 2050 feet A. T. (boulders), no. 8.

2754 Loose near head of side valley about 1 mile east of Cuba-Clarksville road and 2 miles south of Cuba-Clarksville boundary. 2065 feet A. T., no. 7.

2755 Roadside cut Clarksville-Haskell road ½ mile east of its junction with Haskell road. 1790 feet A. T., no. 11.

2756 Head of ravine by roadside in northwestern corner of Clarksville township. 1755 feet A. T., no. 11.

2757 Armstrong quarry near Erie depot, Cuba. 1555 feet A. T.

2758 Ravine on east side of hill west of road to North Cuba, ½ mile north of Cuba village. 1700 feet A. T., no. 12.

2759 From 2–3 miles east of west county line, about ½ mile north of Cuba-Clarksville boundary. 1960 feet A. T., no. 9.

2760 Ravine 3 miles south of Cuba on road branching from second road to left from Clarksville-Cuba road going south. [Cu 156 $^{1 \,\&\, 2}$] 1785, 1760 and 1735 feet A. T., no. 11. [Cu 156 $^{3 \,\&\, 4}$] 1855 and 1875 feet A. T., no. 10; [Cu 156^{5}] 1925 feet A. T., no. 9.

2761 Ravine on west side of Cuba-Clarksville road, 3 miles south of Cuba. 1760 feet A. T., no. 11.

2762 Along stream about 3½ miles southwest of Cuba. 1675 feet A. T., no. 11.

2763 Ravine in southwest corner of Cuba township, 3 miles southwest of Cuba. 1705 feet A. T., no. 12.

2764 Creek bank ¼ mile west of Cuba reservoir just west of county line; 1590 feet A. T., no. 13.

2765 Ravine 2 miles southeast of Cuba. 1732 feet A. T., no. 11.

2766 Field in elbow of road 2½ miles southeast of Cuba village; also loose in vicinity of high hill from 1–2 miles north of Cuba-Clarksville boundary. [Cu 185] 1900 feet A. T. (loose), no. 8; [Cu. 186^{1}] 2115 feet A. T., no. 8.

2767 Road up hill from summit between Cuba and Friendship, Allegany co. in southwesterly direction in southern central part of Cuba township. 1790, 1860, 1870 feet A. T., no. 10?

2768 Ravine on west side of valley $\frac{3}{4}$ mile south of Cuba. 1560, 1570, 1585, 1600, 1635 feet A. T., no. 12; 1750, 1790, 1800 feet A. T., no. 11.

2769 River flats west of Bullis's mill near state line, Eldred township, McKean co. Pa. 1415 feet A. T. (boulders), no. 8. Position?

2770 Road banks Portville-Eldred road $\frac{1}{2}$ mile east of intersection of Louds creek, Eldred township, McKean co. Pa. 1415 feet A. T., no. 9.

2771 Roadside cut on Portville-Eldred road, near river, about 7 miles from Portville in Eldred township, McKean co. Pa. [E 98] 1425 feet A. T., no. 9; [E 98^1] 1425 feet A. T. (loose), no. 8.

2772 Shale bank by roadside 1 mile north of Eldred Pa. near mouth of Indian creek. 1450 feet A. T., no. 9.

2773 Roadside ditch of road southeastern corner of Friendship, Allegany co. between lots 2 and 3. 2075 feet A. T., no. 9?

2774 Ravine entering Ischua valley from northeast, in southeastern corner of Franklinville township. 1750 feet A. T., no. 12.

2775 Road over high hill in southeastern part of Franklinville township; east side. [F 202] 1780 feet A. T., no. 12; [F 202^1] 1995 feet A. T., no. 10; [202^{2-4}] 2030, 2100, 2150 feet A. T., no. 9.

2776 Road running due east and west $\frac{1}{3}$ mile north of Humphrey-Franklinville boundary, southeastern part of Franklinville township. 2235 feet A. T., no. 9.

2777 Southeastern corner of Friendship township. 2235 feet A. T., no. 8?

2778 Field on top of high hill in angle formed by roads in middle of southern part of Franklinville township on lot 17, $\frac{1}{2}$ mile north of Franklinville-Humphrey boundary. 2250 feet A. T., no. 8.

2779 Loose; crest of ridge, Rock City, Genesee township, short distance west of rocks. 2310 feet A. T., no. 3.

2780 Roadside cut about 1 mile east of Carroll, Genesee township. 1490, 1500 feet A. T., no. 11.

2781 Cut on Western N. Y. & C. R. R. ½ mile east of Ceres, Genesee township, near Bowler station. 1510 feet A. T., no. 11.

2782 Cut on abandoned railroad at highway crossing at west branch of Windfall creek, about 3 miles north of Little Genesee. 1700 feet A. T., no. 9.

2783 North side of hill between Coon hollow and Deer creek, Genesee township; outcrop in road. 1860 feet A. T., no. 9.

2784 Woodchuck hollow, ¼ mile from intersection with Olean-Hinsdale road. 1460, 1500, 1505 feet A. T., no. 12.

2785 Near mouth of Gull brook about 1 mile west of Hinsdale, also loose in forks of road west of Gull brook. [H 136] 1510, 1520 feet A. T., no. 12; [H 137] 1970 feet A. T. (loose), no. ?

2786 Head of Fay hollow, Hinsdale. 1950 feet A. T., no. 9.

2787 Near summit of Fay hollow about 1 mile north of Pennsylvania R. R. 1525 and 1585 feet A. T., no. 12.

2788 Ravine 50 yards north of Erie depot, Hinsdale, east of railroad track. 1500 feet A. T., no. 12.

2789 Bank of creek in eastern part of Hinsdale township near county line, about 3½ miles northeast of Haskell Flats. 1690 feet A. T., no. 11.

2790 Ravine ½ mile northwest of Haskell Flats, ¼ mile west of junction of roads. 1630 feet A. T., no. 11.

2791 Cut by roadside, road from Scotts Corners eastward to Haskell Flats, Hinsdale township. 1840 feet A. T., no. 9.

2792 Old quarry on hillside just west of Haskell Flats. 1695 feet A. T., no. 10.

2793 Roadside ditch on spur of 2185 feet summit, 3 miles southwest of Cuba. 2045 feet A. T., no. 9.

2794 Top of hill about 2 miles southwest of Cuba. 2045 feet A. T., no. 9.

2795 2170 feet summit west of Oil creek, half way between Cuba and Hinsdale. 2170 feet A. T., no. 9.

2796 Ravine on west side of Oil creek valley about 3 miles northeast of Hinsdale. 1585 feet A. T., no. 12.

2797 Road north and south over 2150 feet summit just south of Hinsdale-Ischua boundary, $1\frac{1}{4}$ miles east of northwestern corner of Hinsdale township. 2100 feet A. T., no. 9.

2798 Mouth of ravine entering Oil creek on valley from northwest, 3 miles west of Cuba. 1540 feet A. T., no. 12.

2799 Summit of Dutch hill, Hinsdale township. 2235, 2220 feet A. T. (loose). Horizon?

2800 Mouth of ravine entering Ischua valley from northeast $\frac{2}{3}$ of a mile north of Scotts Corners. 1555 feet A. T., no. 12.

2801 Roadside 1 mile due north of Humphrey Center. [Hu 206] 1920 feet A. T., no. 8?; [Hu 206^1] 1845 feet A. T. (loose), no. 9?

2802 Hill road from Humphrey Center to Cooper's hill; west side. [Hu 207] 1770 feet A. T., no. 9? [Hu 207^1] 1930 feet A. T., no. 9.

2803 Roadside top of Cooper's hill, northwestern part of Humphrey township; loose. 2225 feet A. T., no. 8?

2804 From head, down to near mouth of ravine entering valley of Five Mile creek from north, just west of Ischua-Humphrey boundary. [Hu 210^1] 1945 feet A. T.; [Hu 210^2] 1870 feet A. T.; [Hu 210^3] 1850 feet A. T., no. 10; [Hu 210^4] 1790 feet A. T.; [Hu 210^5] 1760 feet A. T., no. 11.

2805 Northern end of Ischua township about 2 miles west of south end of Cuba reservoir; also loose top of 2217 feet summit slightly southwest of reservoir. [I 178] 2080, 2130 feet A. T., no. 9; [I 179] 2210 feet A. T., no. 9.

2806 Ravine intersecting Oil creek valley from northwest 2 miles west of Cuba. 1670 feet A. T., no. 12.

2807 Outcrop by stream 1 mile due east of Ischua depot, south side of valley. 1615 feet A. T., no. 12.

2808 Road running east from Ischua; about 1 mile east of Ischua. 1718, 1800 feet A. T., no. 11.

2809 Road running east from Ischua, from 2-3 miles east of village. 1820 feet A. T., no. 10.

2810 Road running east of Ischua, 1⅓–2 miles east of village. [1 195^{3-8}] 1935, 1995, 2020, 2030, 2065, 2050 feet A. T.; no. 9.

2811 Ravine running northeast from road 1 mile northwest of Ischua. 1545 feet A. T., no. 12.

2812 Ravine entering Ischua valley from east, 4 miles south of Ischua; ¼ mile up ravine from main road. 1610 feet A. T., no. 12.

2813 Deep gorge running north from road 3 miles southeast of Ischua; 50 yards up gorge. 1860 feet A. T., no. 11.

2814 Near 2015 feet summit, 1 mile north of Hinsdale-Ischua boundary, in Ischua township. 2000 feet A. T., no. 9

2815 Near road 4 miles south of Ischua. 1810 feet A. T., no. 11.

2816 Roadside 4½ miles south of Ischua. 2040 feet A. T., no. 9.

2817 Top of Learn hill, northern part of Ischua township. 2160–2280 feet A. T. (loose), no. 7 or 8.

2818 East bank of Ischua creek, ¼ mile south of Ischua. 1590 feet A. T., no. 13.

2819 Road running near middle of Lyndon township, ¼ mile north of Lyndon-Ischua boundary. 2080 feet A. T., no. 9.

2820 Southwest corner of Lyndon township, just southeast of four corners ½ mile east of Lyndon-Franklinville boundary and 1¼ miles north of Lyndon-Ischua boundary. 2140 feet A. T., no. 11.

2821 Quarry below reservoir about 1 mile south of Olean. 1560 feet A. T., no. 11.

2822 Near brow of steep escarpment facing north; 1¼ miles south of Olean. 1745, 1750, 1760, 1765, 1890, 1900 feet A. T., no. 9.

2823 Old quarry on north slope of Mount Hermon. 1970 feet A. T., no. 7.

2824 Old quarry on west side of Mount Hermon, about 4½ miles south of Olean. 2040 feet A. T., no. 7.

2825 Quarry on west side of Mount Hermon, 1½ miles south of Olean. 2150–2178 feet A. T., no. 6.

2826 Quarry on east side of Mount Hermon. 2150 feet A. T., no. 6.

2827 South slope of Mount Hermon about 3 miles south of Olean. 2100 feet A. T., no. 6.

2828 Cook's quarry, 3–4 miles south of Olean; head of Wildcat hollow. 2000 feet A. T., no. 7.

2829 Old quarry at base of hill on west side of Wildcat creek, 1½ miles southwest of Olean. 1545 feet A. T., no. 12.

2830 Bench on northeast side of hill 2½ miles southwest of Olean. 1960–2025 feet A. T., no. 7.

2831 Road at Four Mile crossing just above the Olean, Rock City & Bradford trolley road. 2200, 2275, 2300 feet A. T., no. 3.

2832 Top of high hill with masses of conglomerate, 3½ miles slightly southwest of Olean. 2300 feet A. T., no. 3.

2833 Quarry in Mount Hermon sandstone, Two Mile valley, 4 miles southwest of Olean. 2090 feet A. T., no. 11.

2834 Cut on old narrow gage railroad from 3–5 miles southwest of Olean; also loose on bank of excavation. 1920–50 feet A. T., no. 7.

2835 3½ miles southwest of Olean. 2125 feet A. T., no. 5.

2836 Cut on abandoned narrow gage railroad between Two Mile and Four Mile valleys, 2½ miles northeast of Rock City. 2160, 2170 feet A. T., no. 4.

2837 Old quarry east of road, and on north side of hill on road from Wayman branch to Olean about 1 or 2 miles southeast of Olean. 1650, 1775, 1875, 1900 feet A. T., no. 9.

2838 Quarry on road from Wayman branch to Olean, 1–3 miles southwest of Olean. 2050 feet A. T., no. 8.

2839 Woods at east of 2240 feet hill, ½ mile south of Wayman branch, 4 or 5 miles southeast of Olean. 1750 feet A. T., no. 9.

2840 Near top of 2240 feet summit, southeast corner of Olean township. 2175 feet A. T., no. 3.

2841 West side of Mount Hermon by road leading to quarry at top, 1½ miles south of Olean. 1940 feet A. T., no. 7.

2842 Quarry about 1¼ miles south of Olean in ravine on east side of Wildcat hollow road. 1560 feet A. T., no. 11.

2843 Escarpment of spur above quarry ½ mile northwest of Olean. 1680 feet A. T., no. 10; 1745 feet A. T., no. 9.

2844 Mouth of ravine ½ mile north of oil refineries, Olean. 1500 feet A. T., no. 11.

2845 On Western N. Y. & Pa. R. R. (Bradford division) 4 miles southwest of Olean. 1750, 1850 feet A. T., no 9.

2846 Cut on Pennsylvania R. R. near United pipe line pumping station, Olean. 1450 feet A. T., no. 12.

2847 Near mouth of Louds creek near New York-Pennsylvania boundary. 1480 feet A. T. (loose), no. 8?

2848 Outcrops at spring by roadside 2½ miles northwest of Olean. 1640 feet A. T., no. 10.

2849 Old quarry on hillside west of Olean-Hinsdale road just south of Woodchuck hollow. 1670 feet A. T., no. 10.

2850 Old quarry on second road west from Olean. 1670 feet A. T., no. 10.

2851 Quarry ½ mile northwest of Erie depot, Olean. 1650 feet A. T., no. 10.

2852 Bank of Dodges creek just above bridge on northeastern outskirts of Portville. 1445, 1480 feet A. T., no. 11.

2853 Loose; top of bench on north side of 2224 foot hill 1 mile west of Portville. 2050 feet A. T., no. 3.

2854 West side of Wolf run opposite 2378 foot summit. [P 72] 1620 feet A. T., No. 11.

2855 North bank of Haskell creek about 3 miles northeast of Boardman. 1600 feet A. T., no. 11.

2856 Roadside cut on summit between Boardman and Haskell creek. 1750 feet A. T., no. 9.

2857 South bank of Allegany river at Weston Mills, opposite Riverhurst park. 1420 feet A. T., no. 11.

2858 Just west of Haskell creek, opposite junction of Wolf run. 1550 feet A. T., no. 11.

2859 Outcrop in field by road to Wayman branch $\frac{1}{2}$ mile southwest of bridge at Portville. 1500 feet A. T., no. 11.

2860 Loose; south of first summit of ridge south of bridge across the Allegany river at Portville. No. 7.

2861 Cut on Pennsylvania R. R. near bridge over Oswayo creek $\frac{1}{4}$ mile south of Portville. 1435 feet A. T., no. 11.

2862 Loose in field north of Carrollton. 1470 feet A. T., no. 8.

2863 Road on south bank of Allegany river in southwest outskirts of Portville. 1450 feet A. T. (loose), no. 11?

2864 Near head of west branch of Gull brook, 3 miles southwest of Ischua. 1890 feet A. T., no. 11.

2865 Loose; south spur of 2100 feet hill about $2\frac{1}{2}$ miles northwest of Allegany. 1910, 1960 feet A. T., no. 7.

2866 Quarry on east side of Cuba reservoir near dam. 1595 feet A. T., no. 13.

2867 Roadside, bank of Indian creek, Eldred, McKean co. Pa. 3–4 miles south of state line. 1540 feet A. T., no. 9.

2868 Roadcut 100 rods north of Bowler station on Central New York and Western R. R. Genesee township. 1560, 1600 feet A. T., no. 11.

2869 From block of hard sandstone firmly embedded in road and ditch, 2 miles south of Little Genesee. 1850 feet A. T., no. 9?

2870 Road on top of hill 1 mile east of Hinsdale. 1980 feet A. T., no. 9.

2871 Road ditch on boundary between Ischua and Hinsdale in northwestern corner of northern jog of Hinsdale. 2020 feet A. T., no. 9.

2872 Ravine on west side of valley $\frac{1}{2}$ mile south of Cuba. 1600 feet A. T., no. 12.

2873 Roadcut at northeast of Dutch hill in northwestern corner of Hinsdale township. 1810 feet A. T., no. 10.

2874 Outcrop of sandstone $\frac{1}{3}$ mile northeast of Ischua depot near road forking. 1610 feet A. T., no. 12.

Locality numbers 2875–2900 and 3057–3094 represent fossils collected by Charles Butts during 1901 in area covered by the

Salamanca quadrangle, Cattaraugus co. The horizons of this area are numbered as follows, beginning at the top:

1 Limestone
2 Olean conglomerate
3 Shales and sandstones
4 Salamanca conglomerate
5 Shales and sandstones
6 Wolf creek conglomerate
7 Shales and sandstones
8 Shales and sandstones. Orthothetes zone
9 Cuba sandstone

2875 At angle in road after passing north over hill at head of Newton run, 3½ miles north of Salamanca. Station 313, no. 5.

2876 North side of road from Little Valley creek to Ellicottville near top of hill, ½ mile southwest of Ellicottville. Station 314, no. 7.

2877 Riverside drive 1 mile south of Ellicottville. Station 315, no. 8.

2878 West side of Great Valley creek, about 1½ miles southwest of Great Valley. Station 316, no. 8.

2879 Face of steep bluff west of Great Valley creek, 1½ miles southwest of Great Valley. Station 317 and 317[1], no. 7.

2880 Head of Mutton hollow just north of northern boundary of Salamanca sheet. Station 318, no. 4.

2881 Cut on Buffalo, Rochester and Pittsburg railroad about 2½ miles north of Great Valley. Station 319, no. 7.

2882 Road about ½ mile northeast of Killbuck station. Station 320, no. 7.

2883 Old road over north side of hill, 2–3 miles northeast of Killbuck. Station 321, no. 7.

2884 Head of hollow about 1 mile south of Peth. Station 322, no. 7.

2885 Near mouth of Barker run. Station 323, no. 8.

2886 Collected west of head of Barker run. Station 324, no. ?

2887 Near 2180′ summit, slightly southeast of Sugartown. Stations 325, 325^1, no. 7.

2888 Road west of Five Mile creek and 2–3 miles southwest of Cooper hill. Stations 327, 327^1, no. 7.

2889 Road about ¾ mile south of summit of Cooper hill. Station 328, no. 7.

2890 One mile south of Cooper hill and ¾ mile west of county line, Humphrey township. Station 329, 329^{1-3}, no. 7.

2891 Road ditch on Wrights creek road near head, about ¾ mile northwest of Bozard hill. Station 330, no. 7.

2892 Road about ¾ mile northwest of Humphrey Center. Station 331, no. 7.

2893 Road short distance north of crest of ridge at head of Nine Mile creek. Station 332, no. 7 (loose).

2894 State line on Olean, Rock City and Bradford trolley road. Station 333, 333^{1-4}, no. 2.

2895 In road near head of Limestone brook. Station 334, no. 3; station $334^{1, 2}$, no. 4.

2896 Limestone brook, 2–3 miles west of Limestone. Station 335, no. 7.

2897 Near head of southwest branch of Limestone brook. Station 336, no. 3.

2898 Summit of high hill just north of state line and near boundary between Salamanca and Carrollton townships. Station 337, no. 2.

2899 Near head of east branch of Bolivar creek, Bradford co. Pa. Station 338, no. 2; station 338^2, no. 1.

2900 Trolley cut ⅛ mile west of Knapp Creek. Station 339, no. 2. 20–30 feet below summit at Knapp Creek on road to Four Mile. Station 339^1, no. 3.

For continuation of localities in Salamanca quadrangle area see record numbers 3057–3093.

The following localities from 2901-48 represent material from the collection donated by J. M. Clarke, 1901. On the tickets each of these numbers is preceded by the letter C.

2901 Hamilton shales. Various localities on Canandaigua lake. J. M. Clarke, donor. 1901.

2902 Hamilton shales. Centerfield, Ontario co. J. M. Clarke, donor. 1901.

2903 Marcellus shale. Flint creek, Ontario co. J. M. Clarke, donor. 1901.

2904 Marcellus shale (Stafford limestone). Stafford, Genesee co. J. M. Clarke, donor. 1901.

2905 Genesee shale (Styliola limestone). Canandaigua lake. J. M. Clarke, donor. 1901.

2906 Genesee shale. Bristol Center, Ontario co. J. M. Clarke, donor. 1901.

2907 Genesee shale. Livingston co. J. M. Clarke, donor. 1901.

2908 Genesee shale; base of shales. Bell's gully, Canandaigua lake. J. M. Clarke, donor. 1901.

2909 Naples beds. Various outcrops in the Naples valley. J. M. Clarke, donor. 1901.

2910 Naples beds; goniatite layer. Parrish gully, Naples, Ontario co. J. M. Clarke, donor. 1901.

2911 Naples beds. Mount Morris, Livingston co. J. M. Clarke, donor. 1901.

2912 Naples beds. Cashaqua creek. J. M. Clarke, donor. 1901.

2913 Naples beds. Honeoye lake; mostly young goniatites. J. M. Clarke, donor. 1901.

2914 Naples beds. Conesus lake. J. M. Clarke, donor. 1901.

2915 Naples beds. Rock stream, Yates co. J. M. Clarke, donor. 1901.

2916 Chemung beds. Elmira. Goniatites. J. M. Clarke, donor. 1901.

2917 Middle Devonic (Goniatitenkalk). Bredelar, Westphalia. J. M. Clarke, donor. 1901.

2918 Onondaga limestone. Canandaigua town. J. M. Clarke, donor. 1901.

2919 Helderbergian. Albany co. J. M. Clarke, donor. 1901.

2920 Naples beds; sandstone slabs from upper layers with goniatites. Naples valley. J. M. Clarke, donor. 1901.

2921 Naples beds; lower black band. Cashaqua creek. J. M. Clarke, donor. 1901.

2922 Naples beds; Conodont layer. Base of Hatch hill, Naples. J. M. Clarke, donor. 1901.

2923 Naples beds; upper black band. Sparta town. Cut on D. L. & W. R. R. 6½ miles northwest of Dansville, Livingston co. Fish remains. J. M. Clarke, donor. 1901.

2924 Wiscoy beds. Castile, Wyoming co. J. M. Clarke, donor. 1901.

2925 Genesee shales; bituminous band. Woodville, Ontario co. J. M. Clarke, donor. 1901.

2926 Genesee shales. Various localities on Canandaigua lake. J. M. Clarke, donor. 1901.

2927 Genesee shales. Gull berg, Honeoye lake. J. M. Clarke, donor. 1901.

2928 Genesee shales; upper layers. Yates co. J. M. Clarke, donor. 1901.

2929 Genesee shale (Styliola limestone), Bristol Center, Ontario co. J. M. Clarke, donor. 1901.

2930 Naples beds. Hamilton gully, Honeoye lake. J. M. Clarke, donor. 1901.

2931 Chemung beds. Alfred, Allegany co. J. M. Clarke, donor. 1901.

2932 Chemung beds. Avoca, Steuben co. J. M. Clarke, donor. 1901.

2933 Chemung beds; lower. Prattsburg, Steuben co. J. M. Clarke, donor. 1901.

2934 Outlier of Ithaca beds; third falls of Grimes gully, Naples, Ontario co. J. M. Clarke, donor. 1901.

2935 Chemung beds. Base of High point, Naples. J. M. Clarke, donor. 1901.

2936 Marcellus shales with spores. Canandaigua. J. M. Clarke, donor. 1901.

2937 Chemung beds. Near Wellsville, Allegany co. J. M. Clarke, donor. 1901.

2938 Oneonta sandstone with Amnigenia. Oxford, Chenango co. J. M. Clarke, donor. 1901.

2939 Naples beds. Java Village, Wyoming co. J. M. Clarke, donor. 1901.

2940 Genesee shales; top layer. Lodi Falls, Seneca co. J. M. Clarke, donor. 1901.

2941 Genesee shales (Styliola limestone), Yates co. J. M. Clarke, donor. 1901.

2942 Naples beds. Pontiac, Erie co. J. M. Clarke, donor. 1901.

2943 Naples beds. Fox's point, Lake Erie. J. M. Clarke, donor. 1901.

2944 Naples beds, loose blocks containing Ithaca fossils. Canandaigua lake. J. M. Clarke, donor. 1901.

2945 Marcellus shale. Slate rock falls 4 miles south of Geneva, Ontario co. J. M. Clarke, donor. 1901.

2946 Chemung beds. Canandaigua. J. M. Clarke, donor. 1901.

2947 Utica slate. Dolgeville, Herkimer co. J. M. Clarke, donor. 1901.

2948 Helderbergian. Orange co. J. M. Clarke, donor. 1901.

2949 Helderbergian. Cumberland Md. Ward & Howell purchase. 1901.

2950 Rondout waterlimes. Loose at Canandaigua. J. M. Clarke, collector. 1901.

2951 Hamilton shales. Robertson's quarry, Canandaigua. J. M. Clarke, collector. 1901.

2952 Salina beds. Black shales below green shales. Bottom of Erie canal, 1½ miles northwest of Pittsford, Monroe co. J. M. Clarke, collector. 1901.

2953 Guelph dolomite. Elora Ont. J. M. Clarke, collector. 1901.

2954 Marcellus shales. Canandaigua. J. M. Clarke, collector. 1901.

2955 Ithaca beds. North glen at McKinney's, Cayuga lake. 100 yards above falls. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2956 Ithaca beds. South glen at McKinney's, Cayuga lake. 100 yards above high falls. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2957 Lower Portage beds. ½ mile below Esty glen, Tompkins co. along railroad track. At this place the Genesee is about 12 feet above the lake and contact between Genesee and Portage is well shown, the former capped by a hard blue sandstone 2½ feet thick. C. A. Hartnagel and H. S. Mattimore collectors. 1901.

2958 Lower portage beds. Asbury, below Bower's mill falls, ¼ mile east of Portland. 980 feet A. T. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2959 Lower Portage beds. Asbury, 100 yards below Bower's mill falls, ¼ mile east of Portland. 975 feet A. T. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2960 Ithaca beds. South glen at McKinney's, Cayuga lake. 150 yards above high falls. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2961 Ithaca beds. Right branch of Salmon creek, 3 miles north-northeast of Ludlowville. 540 feet A. T. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2962 Lower Portage beds. First branch of Salmon creek, 1 mile northwest of Ludlowville. 780 feet A. T. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2963 Lower Ithaca beds. Creek bed just east of highway, 1½ miles east of Portland, Cayuga lake. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2964 Ithaca beds. North glen at McKinney's, slightly higher than 2563. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2965 Ithaca beds. South glen at McKinney's, Cayuga lake, above 2564. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2966 Ithaca beds. South glen at McKinney's, Cayuga lake, 50 yards from point where creek divides. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2967 Ithaca beds. Right fork of south glen at McKinney's, where creek divides. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2968 Ithaca beds. Renwick creek, 100 feet above lake; 300 yards from highway at lake. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

This section is not far from the Remington salt works from whose wells the following section was taken:

Portage	240 feet	Onondaga	95 feet
Genesee	125 "	Oriskany	15 "
Tully	30 "	Helderbergian	
Hamilton	1079? "	(waterlimes)	135 "
Marcellus	81? "	Salina	295 "

2137 feet to first salt; total depth 2190 feet.

2969 Ithaca beds. Renwick creek; short distance above 2968. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2970 Ithaca beds. Renwick creek, just above 2969. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2971 Ithaca beds. Foot of Ithaca falls, Fall creek, Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2972 Ithaca beds. Top of Ithaca falls, Fall creek, Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2973 Ithaca beds. Creek bed foot of cascade at electric light plant, Fall creek, Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2974 Ithaca beds. Creek bed just above electric light plant, Fall creek, Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2975 Ithaca beds. Foot of first falls above electric light plant, Fall creek, Ithaca. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2976 Ithaca beds. Top of falls above 2975. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2977 Oneonta beds. Camp Heart's Content, below falls, Lawrence station, Greene co. G. H. Chadwick, collector. 1901.

2978 Ithaca beds. Creek bed at Weaver's falls 1 mile northwest of Groton, Tompkins co. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2979 Ithaca beds. 100 yards above 2978. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2980 Ithaca beds. Ben Hatch farm 2½ miles north of Groton. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2981 Ithaca beds. Hollow brook, Locke, Cayuga co. This station is 2 miles southwest of Locke above Genesee shale, which is exposed in lower portion of brook. C. A. Hartnagel and H. S. Mattimore, collectors. 1901.

2982 Beekmantown limestone. Graptolites. Abandoned quarry 1 mile southeast of Melrose and ½ mile east of Grant Hollow, Rensselaer co. R. Ruedemann and H. S. Mattimore, collectors. 1901.

2983 Guelph dolomite. Balantine's quarry east of river, south of railroad station, Galt Ont. Lowest part of Galt section; according to Logan about middle of formation. J. M. Clarke and D. D. Luther, collectors. 1901.

2984 Guelph dolomite. Hogg's quarry west of river; Galt Ont. About same horizon as 2983. J. M. Clarke and D. D. Luther, collectors. 1901.

2985 Guelph dolomite. Mill dam at Galt Ont. Horizon just above 2984. J. M. Clarke and D. D. Luther, collectors. 1901.

2986 Guelph dolomite. Melross's quarry east of river, 1 mile north of Galt Ont. Top of Galt section. J. M. Clarke and D. D. Luther, collectors. 1901.

2987 Guelph dolomite. Hespeler Ont. According to Logan near base of section. J. M. Clarke and D. D. Luther, collectors. 1901.

2988 Guelph dolomite. Webster's quarry, Galt Ont. J. M. Clarke and D. D. Luther, collectors. 1901.

2989*a-r* Cox's ravine, Cherry Valley, Otsego co.

a Marcellus shale in Cox's ravine below falls

b Marcellus shale directly below Anarcestes bed horizon about 10 feet

c Anarcestes bed; limestone bed 1

d Overlying shale

e Limestone bed 2

f Intercalated shale

i Limestone bed 4

k Intercalated shale

l Limestone bed 5

m Intercalated shale

n Limestone bed 6

o Intercalated shale (on Steenburg farm)

p Limestone bed 7 (base on Steenburg farm)

q Limestone bed; middle part

r Limestone bed; upper part

R. Ruedemann, collector. 1901.

2990 Agoniatites limestone. Lamoreaux farm, 1 mile west of Schoharie. R. Ruedemann, collector. 1901.

2991 Marcellus shale. Stony point, West Seneca, Erie co. B. F. Morgan, collector. 1901.

2992 Chemung beds. Near Union, Broome co. J. Van Deloo, collector. 1901.

2993 Chemung beds. Kirkwood, Broome co. E. B. Hall, donor. 1901.

2994 Chemung beds. Near Tracy Creek, Broome co. E. B. Hall, donor. 1901.

2995 Chemung beds. Ouaquaga, Broome co. E. B. Hall, donor. 1901.

2996 Guelph horizon. On canal feeder 2½ miles south of Shelby, Orleans co. D. D. Luther, collector. 1901.

2997 Chazy beds. Roadside 300 feet west of D. & H. R. R. track at Valcour station, Clinton co. G. van Ingen, collector. 1901.

2998 Chazy beds. Ledges in fields to north of normal school, Plattsburg, Clinton co. G. van Ingen, collector. 1901.

2999 Beekmantown limestone. Along D. & H. R. R. tracks in cut near Burdick's crossing, 1½ miles north of Crown Point, Essex co. G. van Ingen, collector. 1901.

3000 Potsdam sandstone. Bed of Saranac river near "Mill D" at Kent Falls, 7½ miles west of Plattsburg, Clinton co. G. van Ingen, collector. 1901.

3001 Potsdam sandstone. Same locality as 3000, but 60 feet higher and 400+ feet farther down the river. G. van Ingen, collector. 1901.

3002 Potsdam sandstone. In bank of Saranac river above "Mill D" at Kent Falls. Horizon is immediately below that of 3001 and 53 feet above that of 3000. G. van Ingen, collector. 1901.

3003 Chazy limestone. Bed of Saranac river just below the "Main mill dam" about 2 miles west of Plattsburg. G. van Ingen, collector. 1901.

3004 Potsdam sandstone in bed of Little Ausable river at Schuyler Falls, Clinton co. G. van Ingen, collector. 1901.

3005 Chazy limestone at east side of West Chazy to Chazy road, 1½ miles northeast of West Chazy station, Clinton co. G. van Ingen, collector. 1901.

3006 Potsdam-Beekmantown transition beds on road from Champlain to Chazy, west road (westerly of the two south bound roads), at top of hill about 2 miles south of Champlain, Clinton co. G. van Ingen, collector. 1901.

3007 Potsdam sandstone at bridge over Carbeau creek at three corners, ¾ mile west of Coopersville, Clinton co. G. van Ingen, collector. 1901.

3008 Potsdam sandstone in fields on Champlain to Chazy east road about ¾ mile north of the four corners west of Cooperville, Clinton co. G. van Ingen, collector. 1901.

3009 Potsdam-Beekmantown transition beds on Champlain to Chazy east road, 2 miles south of Champlain. G. van Ingen, collector. 1901.

3010 Potsdam-Beekmantown transition beds on Champlain to Chazy east road, 2 miles south of Champlain. Horizon 4 feet above that of 3009. G. van Ingen, collector. 1901.

3011 Potsdam-Beekmantown transition beds on Champlain to Chazy east road, 1½ miles south of Champlain. G. van Ingen, collector. 1901.

3012 Potsdam-Beekmantown transition beds on Champlain to Chazy east road, 1½ miles south of Champlain. Horizon 21 feet above that of 3011. G. van Ingen, collector. 1901.

3013 Beekmantown beds in Marble river at Hill's sawmill, 1 mile above junction of Marble and Chateaugay rivers, 2 miles north of Chateaugay, Franklin co. G. van Ingen, collector. 1901.

3014 Potsdam sandstone in Marble river near Pat Welch's, 1 mile north of Chateaugay, Franklin co. G. van Ingen, collector. 1901.

3015 Potsdam-Beekmantown transition beds in bed of Ticonderoga creek just below the second pulp mill above the village of Ticonderoga, Essex co. G. van Ingen, collector. 1901.

3016 Potsdam-Beekmantown transition beds along shore of Lake Champlain on west side of Mt Independence near A. A. Blood's house, in town of Orwell, Addison co. Vt. G. van Ingen, collector. 1901.

3017 Beekmantown beds in bed of Boquet river in village of Willsboro, Essex co. G. van Ingen, collector. 1901.

3018 Beekmantown beds on shore of Lake Champlain at Fairchild's point at mouth of Boquet river, town of Willsboro, Essex co. G. van Ingen, collector. 1901.

3019 Potsdam sandstone on lake shore at Flat Rock point, 2 miles east of Willsboro, Essex co. G. van Ingen, collector. 1901.

3020 Beekmantown beds. Bed of Salmon river at crossing of Salmon river road at South Plattsburg. G. van Ingen, collector. 1901.

3021 Mytilus edulis bed in raised beach at the "Gravel pit" 1 mile west of Lapham Mills, Clinton co. G. van Ingen, collector. 1901.

3022 Potsdam sandstone in bank of Saranac river at lower end of "Mill D" at Kent Falls, 7½ miles west of Plattsburg. Horizon 258 feet above that of 3000. G. van Ingen, collector. 1901.

3023 Potsdam sandstone in bank of Saranac river at lower end of "Mill D" Kent Falls. Horizon immediately above that of 3022.

3024 Chazy limestone. Road from West Chazy to Chazy, 1½ miles east of West Chazy, Clinton co. G. van Ingen, collector. 1901.

3025 Potsdam-Beekmantown transition beds in bed of Big Chazy river at the Champlain waterworks and dam, 1½ miles west of Champlain, Clinton co. G. van Ingen, collector. 1901.

3026 Potsdam sandstone. On Champlain to Mooers road, 2¾ miles east of Mooers, Clinton co. G. van Ingen, collector. 1901.

3027 Potsdam-Beekmantown transition beds in village of Ticonderoga, near the junction of East Exchange and River streets. G. van Ingen, collector. 1901.

3028 Potsdam-Beekmantown transition beds near the junction of East Exchange and River streets in the village of Ticonderoga. 10 feet above 3027. G. van Ingen, collector. 1901.

3029 Potsdam-Beekmantown transition beds on left bank of Ticonderoga creek at north side of mill, below East Exchange street bridge, Ticonderoga. G. van Ingen, collector. 1901.

3030 Trenton shales in bed of Saranac river at South Catherine street bridge in village of Plattsburg. G. van Ingen, collector. 1901.

3031 Potsdam sandstone. Ausable chasm at the place called "Mecca", just below the "Devil's Oven". Ausable chasm, Clinton co. G. van Ingen, collector. 1901.

3032 Potsdam sandstone. Same layer as 3031 but exposed at the mouth of Mystic gorge in Ausable chasm, about 200 feet down stream from 3031. G. van Ingen, collector. 1901.

3033 Potsdam sandstone. Same layer as 3031, but exposed at west end of Hyde's cave bridge, 300 feet down stream from 3032. Ausable chasm. G. van Ingen, collector. 1901.

3034 Potsdam sandstone. Same layer as 3031, but exposed at upstream end of bridge over Smuggler's pass, 250 feet down stream from 3032. Ausable chasm. G. van Ingen, collector. 1901.

3035 Potsdam sandstone. Same layer as 3031, but exposed at level of path-railing at the "Postoffice", 250 feet down stream from 3034. Ausable chasm. G. van Ingen, collector. 1901.

3036 Potsdam sandstone. Same layer as 3031, but exposed in hillside at upper rapids below Cathedral Rocks at a point about 2100 feet down stream from 3035. Ausable chasm. G. van Ingen, collector. 1901.

3037 Potsdam sandstone. Same layer as 3031, but exposed at top of door on stairway leading up bank from Cathedral Rocks. Ausable chasm. G. van Ingen, collector. 1901.

3038 Potsdam sandstone. Layer just below 3033 at level of path-railing between "Mystic gorge" and "Smuggler's pass", Ausable chasm. G. van Ingen, collector. 1901.

3039 Potsdam sandstone. Hyolithes bed at level of "Table rock" at foot of Cathedral Rocks, Ausable chasm. G. van Ingen, collector. 1901.

3040 Potsdam sandstone. Same layer as 3039, but exposed in hillside at Upper Rapids below Cathedral Rocks, Ausable chasm. G. van Ingen, collector. 1901.

3041 Potsdam sandstone. Obollela layer, 15 feet above 3036 in hillside at Upper Rapids below Cathedral Rocks, Ausable chasm. G. van Ingen, collector. 1901.

3042 Potsdam sandstone. Obolella layer at top of Cathedral Rocks, 50 feet above 3036, Ausable chasm. G. van Ingen, collector. 1901.

3043 Chazy limestone. Drift on shore of Lake Champlain at Port Kent. G. van Ingen, collector. 1901.

3044 Beekmantown beds. In field west of D. & H. R. R. track and north of wagon road that crosses the railroad 1 mile north of Beekmantown station, Clinton co. (Whitfield's locality of Ophileta beds. Am. mus. nat. hist. 2) G. van Ingen, collector. 1901.

3045 Potsdam sandstone. Layer with Linguloid shells 15 feet above 3039 at foot of stairs leading up cliff at Cathedral Rocks in Ausable chasm. G. van Ingen, collector. 1901.

3046 Chemung beds. West hill, Lincoln gully, Naples. 1380 feet A. T. D. D. Luther, collector. 1901.

3047 Lockport (?) dolomite. Pittsford; on Allen creek ½ mile west of canal. D. D. Luther, collector. 1901.

3048 Guelph dolomite. Galt, Ont. William Herriot, donor. 1902.

3049 Chemung beds. Hamlin pasture 2 miles southeast of Naples on Knapp hill. D. D. Luther, collector. 1901.

3050 Chemung or Ithaca beds. West hill above Cumming's crossing, Naples. D. D. Luther, collector. 1901.

3051 Lockport (?) dolomite. Pittsford; on Allen creek between canal and Auburn R.R. D. D. Luther, collector. 1901.

3052 Salina beds. Black shale lying at or near the base of the Salina formation. Pittsford; canal bank near Cold Spring House. D. D. Luther, collector. 1901.

3053 Chazy limestone. Day point, Valcour. G. van Ingen, collector. 1901.

3054 Portage (Ithaca) shales. Spafford, Onondaga co. D. D. Luther, collector. 1895.

3055 Naples shales. Plum creek, village of Himrod, Yates co. 170 feet above Seneca lake. J. M. Clarke, collector. 1895.

3056 Naples shales. Belknap's gully 2 miles north of Branchport, Yates co. J. M. Clarke, collector. 1895.

Continuation of record of localities of fossils collected in area covered by Salamanca quadrangle. Charles Butts, collector. 1901. See section, 2875.

3057 2 miles slightly southwest of Salamanca; road about 2000′. Station 260, no. 7.

3058 Cut by roadside about 2 miles southwest of Salamanca, ¼ mile above and west of station 260. Station 261, no. 3.

3059 Near triangulation station on top of 2375′ summit, east of south of Salamanca. Station 264, no. 3.

3060 Short distance south of cross roads, up Beehive creek. Station 265, no. 7.

3061 Hillside east of junction of Bova and Red House creeks. Station 266, no. 7.

3062 Hillside east of junction of Bova and Red House creeks; 40 feet above station 266. Station 267, no. 7.

3063 Crest of nose east of junction of Bova and Red House creeks. Station 268, no. 7.

3064 Buffalo, Rochester and Pittsburg railroad cut near highway crossing at Carrollton. Station 271, no. 8.

3065 Old quarry just above highway, short distance south of Carrollton. Station 272, no. 7.

3066 Top of nose nearly 1 mile due east of Carrollton. Station 273, no. 7.

3067 Crest of nose east of Carrollton. Station 275, no. 3.

3068 15 feet of top of 2200′ summit east of Carrollton. Station 276, no. 3.

3069 Roadside head of hollow, little over 1 mile southeast of Sugartown, Humphrey township, near western boundary. Station 326, no. 7.

3070 West side of hill between Chipmunk and Tuna creeks. Station 278, no. 7; station 277, no. 7.

3071 Crest of ridge between Chipmunk and Tuna creeks, nearly due east of Irvine Mills. Station 280, no. 4.

3072 Near forking of Irish and Rice brooks, west of Tuna creek. Station 281, no. 7.

3073 Roadside a few rods west of road forking Irish brook and Rice brook roads. From boulder. Station 282, no. 4.

3074 Near top of hill at head of Irish brook. Station 285, no. 3.

3075 In road near east branch of Red House brook. Station 287, no. 4.

3076 Short distance south of Halls, Red House brook road. Station 288, no. 7.

3077 Just north of summit by road, 3 miles north of Salamanca, at head of Newton run. Station 312, no. 3.

3078 Road near McIntosh creek $1\frac{1}{2}$ miles from Red House brook. Station 289, no. 7.

3079 Crest of ridge between Tuna and Chipmunk creeks. Station 291, no. 4.

3080 North slope of ridge between Tuna and Chipmunk creeks. Station 292, no. 4.

3081 North slope of ridge between Tuna and Chipmunk creeks, 30 feet below station 292. Station 293, no. 7.

3082 1 mile east of Riverside junction, Carrollton township, 50 feet below station 294. Station 295, no. 7.

3083 1 mile east of Riverside junction, Carrollton township, 50 feet below station 295. Station 296, no. 7.

3084 Roadside just south of junction of roads at twine mills, Tuna Valley. Station 297, no. 7.

3085 Hill north side of Killbuck station. Stations 298–300, no. 7.

3086 Hill south of Salamanca. Station 302, no. 7; station $302^{1, 2}$, no. 7; station $302^{3, 4}$, no. 4.

3087 Cut on Buffalo, Rochester and Pittsburg railroad, 2 miles east of Salamanca. Station 303, no. 7.

3088 Cut on Buffalo, Rochester and Pittsburg railroad, 3–4 miles east of Salamanca. Station 304, no. 8.

3089 Spur west of Carrollton and west of river. Station 305, no. 7.

3090 Roadside on road northwestward up Great Valley creek, about $\frac{3}{4}$ mile north of Killbuck station. Station 306^1, no. 7.

3091 Road, Hungry hollow, 3 miles west of Great Valley. Station $307^{1, 2}$, no. 7.

3092 Newton run $\frac{3}{4}$ mile north of Salamanca. Station 310, no. 7.

3093 Old quarry about 1 mile north of Salamanca up Newton run. Station 311, no. 7.

RECORD OF FOREIGN LOCALITIES

Specimens bearing lemon yellow tickets

105 Taunus quartzite (lowest Devonic). Katzenloch near Idar, Rhineprovince. E. Kayser, Marburg, donor. 1900.

106 Siegen grauwacke. Siegen, Germany. E. Kayser, Marburg, donor. 1900.

107 Upper Siluric. Island of Oesel, Livonia, Russia. Purchased of Dr F. Krantz (Mineralien-Contor) Bonn, Germany. 1901.

APPENDIX 3

CONTACT LINES OF UPPER SILURIC FORMATIONS ON THE BROCKPORT AND MEDINA QUADRANGLES

TRAVERSES BY J. M. CLARKE, R. RUEDEMANN AND D. D. LUTHER, 1901

Brockport quadrangle. *Clinton beds.* At Adams Basin on the Niagara Falls road the Clinton limestones are exposed at one or two points along the banks of Salmon creek. Not far back from the railroad culvert crossing this creek was formerly a small quarry in the cherty thin limestone slabs of the upper Clinton (station 18; 520± feet A. T.).

Station 15. In the bottom of Salmon creek at crossing of first east and west road south of Adams Basin, thin relatively pure Clinton limestones with Hyattella congesta (elevation 525 feet A. T.).

Still farther up stream and along the east branch about ⅓ mile are more silicious Clinton flags lying close to the top of the series.

Rochester shale. Station 17; 20 rods beyond this point on the same stream is an outcrop of Rochester shale with Spirifer radiatus, Dalmanites limulurus, etc. This is the base of the Rochester shale and its elevation is 570 feet A. T. The change from the Clinton to the Niagara shale is not marked by topographic features and there appears to be no surface evidence of the passage of the one formation into the other. South of Spencerport the contact line crosses the creek running through that village at just about or near Ogden Center, and follows approximately the 600 foot contour line. To the west the topography indicates no abrupt or noteworthy change in the position of this line but outcrops are of very rare occurrence. In the traverse from Adams Basin southward no other outcrops of the Niagara shale were observed.

Lockport dolomites. Station 14. Elevation 625 feet A. T. This is a spot on the farm of E. Arnold, township of Ogden just east of the highway leading due south from Adams Basin where a thin, quite pure somewhat crinoidal dolomite has been taken out in small quantity for local construction purposes.

As the differences in surface elevation between this limestone and the outcrop of Niagara shale previously noted is but about 45–50 feet and the north-south interval between the two stations about 1 mile, it is evident that this is one of the layers, if not the basal bed, of the series of Lockport dolomites. The exposed thickness here is from 1–2 feet.

Station 13. At the four corners due south of station 14 in a field to east of road is an outcrop of gray, somewhat scraggy dolomite, 3 feet. Elevation on topographic sheet approximately the same as that of station 14, the stratum probably lying close on that exposed at former station. These scraggy dolomites carrying some silicious nodules and silicified fossils (Favosites, Stromatopora, etc.), their roughened surfaces due to unequal weathering, are exposed at various points to the east and west of this road north and south of the hamlet of Ogden and from the elevation stated where they immediately overlie the rock at station 13, through an interval of about 40 feet. These outcrops are also to be observed freely throughout the region east and west, specially along the first east and west road north of the Ogden road, and from there westward.

Stations 12, 11, 10, 6, 5 and 4. These very characteristic scraggy dolomites vary little in texture and color. For the most part the outcrops show the usual rough surface with considerable chert often replacing the corals but so far as observed other fossils than corals or Stromatopora are seldom present. Here and there, as at station 11 on the north and south road the first east of the Ogden-Churchville highway, the rocks have a smoother, more homogeneous character and carry less chert. This layer however appears to be one intercalated between other layers of the more silicious material. Similar exposures of these dolomites indicated for the most part by boulders loose above concealed outcrops, are to be seen over the territory to the west, approximately along the boundary line between the towns of Bergen and Sweden.

Salina beds. The lower limit of the Salina in this section is indicated by an outcrop on the road from Churchville to North

Chili and lying about half the distance between these two points, or 2 miles from Churchville. Here are exposed (station 9) the green shales of the basal Salina. The nearest outcrop of the Lockport dolomite is about 1 mile north of this and ¾ mile to the east, being at station 6 on the first north-south road east of the road from North Chili to Spencerport. No closer approach of the two formations could be observed, but the topography of the region seems to clearly indicate the contact of the limestone with the soft Salina shales above along an approximate east and west line through this region. On account of the drift mantle, the limestone outcrops do not make a specially noteworthy feature of the topography. The extent of the Salina in the vicinity of Churchville and south of North Chili is indicated by outcrops recorded (station 8) just south of Churchville village in drain excavations on the Riga road. Also along the banks of Black creek at station 7, near the confluence with a branch from the west, 1 mile south of Churchville, where are 15 feet of mottled red green and gray shales. At station 1, 3 miles southeast of Churchville, 15 feet of greenish and gray shales are exposed on both sides of the creek and extend in interrupted exposures as far as the road to Buckbee Corners, crossing the creek. Thus it is evident that the region north of Black creek to the last outcrop of the Lockport dolomite, a distance of 3 miles, is covered by the soft shales of the basal portion of the Salina.

Albion quadrangle. *Medina sandstone.* Holley. The extensive quarries in the Medina sandstone about Holley and the sections afforded along the banks of Sandy creek coming in from the south, give an instructive exhibit of the character and variations in this formation. Along the banks of the creek to the north of the town (station 22) are banks of red and green shale 15 feet thick and the lower sandstones are exposed in rather thin red and brownish beds much mottled and interlaminated with white, but with a single heavy homogeneous red layer at the bottom. At a quarry near the towpath at the crossing of the first north-south road east of the village, above the red

sandstone, those of paler color passing into white are shown in the upper exposures along the creek for 1½ miles south of the village. From Holley to Clarendon the Medina extends for apparently about 2 miles but aside from the creek section is covered.

Clinton beds and Rochester shales. At Clarendon (station 23) and along the escarpment west of the east branch of Sandy creek are noteworthy exposures of Clinton limestone, continuing from just north of the village to 1½ miles to the south.

Other exposures of Clinton limestone were not observed and the topography soon becomes depressed so that the existing Rochester shales are, so far as our observations extended in this section, concealed.

Lockport dolomites. At about 1½ miles south of the last observed exposure of the Clinton limestone, just north of the settlement known as Honest Hill, and to the west of the highway leading to Byron, is a small quarry on the Arnold farm from which thin slabs of gray, comparatively pure or slightly dolomitic limestone have been taken and this rock seems to pertain to the base of the Lockport dolomitic series. The country here enters the eastern arm of the Oak Orchard swamp and other outcrops are here concealed, the only additional evidence of the presence of the dolomite series being found at the south edge of this swamp land where occasional accumulations of the scraggy upper dolomites are to be observed. At one point just north of Pumpkin hill on a northerly branch of Black creek these layers were at one time brought together and burned for lime, the kiln and piles of accumulated material still being in evidence. After passing the probable southern limit of the dolomite area approximately along the course of Black creek, the country becomes so low and marshy, specially to the east in the direction of Bergen, that no outcrops are afforded and from Byron to Elba a distance of 6½ miles, and from Elba north to Langton Corners, 1 mile, and from there north 1½ miles to the east and over various points along that road southward to East Oakfield and thence to Oakfield village, no outcrop could

be ascertained at any place. For this area we are therefore compelled to construct from the data brought together from the adjoining territory the probable contact lines, clearly indicated in some places by actual exposures and suggested with strong probability in others.

Medina quadrangle. The country forming the south boundary of the Oak Orchard and Tonawanda creek swamps is likewise barren of any trace of outcrop. The region was carefully traversed from Oakfield, where the gypsum beds of the Salina are extensively wrought, 3 miles to Bumpus triangulation station, thence west to Wheatville, Alabama and West Alabama, south to South Alabama and Smithville station. It is appropriate to note from the conditions here displayed by the topography that the great swamp area which extends entirely across this Medina quadrangle rests on the excavated Salina shales or the dolomite series beneath, from which the shales have been removed.

North from the Tonawanda reservation along the drainage canal running into Oak Orchard creek at a point from $1\frac{3}{4}$ to 1 mile south of Shelby where this channel was excavated through the rock, are exposed a succession of the Lockport dolomites.

Station 27. Where the first east and west road south of Shelby crosses the creek, the lower rock is a bluish gray dolomite weathering brown, in thin rough layers from 3-12 inches thick. Fossils occur in this rock, most abundant of which are Zaphrentis and other corals, with Stromatopora. Above this is a band of coarse grained dark dolomite 4 feet thick, some of the layers of which are quite soft and shaly. Here also are found small corals. At the top of this band is a well defined change in the character of the deposition, the rock becoming a more compact and more heavily bedded brown scraggy dolomite. 6 to 8 feet of this rock are exposed along the creek for a total distance of about a half mile, and a very large amount taken from the channel six or eight years ago is piled up in heaps on the banks. Just above the bridges on the north and south road the rock dips below the bottom of the excavation but is brought

up again 40 rods south by a low ridge and forms the sides and bottom of the channel for nearly ¼ mile, showing about 5 feet of the base of the uppermost layers and at the apex of the fold a foot or two of the shaly layer beneath it. This is the most southern exposure on Oak Orchard creek. Fossils obtained show it to be the horizon of the Guelph dolomite.

Rochester shale. Station 28. The falls at Shelby village. The exposure here shows the lower silicious layers of the Lockport limestone of which about 30 feet are seen in the falls. These beds are very close on the base of the limestone series for at a short distance farther down the stream is an outcrop of the upper Rochester shale bearing a 1 foot silicious bed in the middle of the bluff, and just below on the face of the escarpment which is indicated by the 600 foot contour line of the topographic map is a clean cut exposure of this shale.

Clinton beds. Station 29. No further outcrop is seen along the course of the creek till the southern outskirts of Medina village are reached where (station 30) is an outcrop on the creek bank ¼ mile north of the dam, exposing crystalline crinoidal limestone with well defined Clinton fossils.

Medina sandstone. A few rods farther down (station 31) the creek exposes a white greenish coarse sandstone of the upper Medina, and from there north Medina sandstone exposures are of frequent occurrence throughout the region. From these observations we have the means of identifying with approximate accuracy the contact lines of the Medina-Clinton, Clinton-Rochester and Rochester-Lockport beds.

Relation of the Oak Orchard swamp to these rock formations. A map of sufficient size such as the topographic sheets of Albion and Medina indicating the extent and distribution of the swamp areas in this region, shows that one can not ascribe to any lithologic differences in these formations a sufficient cause for the present area of these swamps. The marsh along the course of Black creek between Byron and Bergen doubtless lies on the Salina shales or is underlain by a pavement of Lockport dolomite where those shales have been removed. But we observe

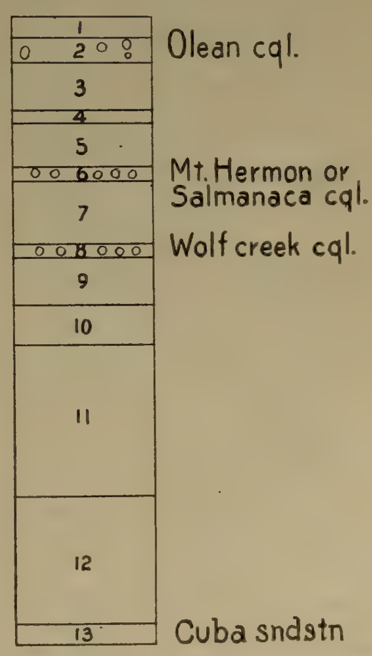
over the area which must be ascribed to the exposures of Lockport dolomites where at least the dolomites must be in main the underlying rock, the considerable, often thin, broken and interrupted extensions of the swamp areas. The rock ridge showing just north of Churchville and North Chili thence westward beyond Shelby, a ridge composed of the Lockport dolomites, may hold the key to the artificial drainage of the major swamp areas. The great body of the swamp north and south covers not only the width of the Lockport dolomite but also that of the Rochester shale and extends farther to the north than it is proper to draw the dividing line between the Clinton and Medina. From this consideration then it becomes evident that the heterogeneous character and the differential erosion of the underlying rocks are not a sufficient cause for the present distribution of the swamp areas, and while this is doubtless an efficient contributory cause for the actual existence of these extensive depressions, their original boundary has been exaggerated by artificial obstruction to drainage.

PRELIMINARY STATEMENT OF THE PALEONTOLOGIC RESULTS OF THE AREAL SURVEY OF THE OLEAN QUADRANGLE

BY JOHN M. CLARKE

In the course of this work undertaken with the cooperation of the U. S. geological survey during the season of 1900, operations were carried on mainly by Prof. L. C. Glenn with the assistance of Charles Butts. Mr Butts was specially concerned in the collection of paleontologic data from all available stratigraphic horizons and the careful study and determination of material accumulated by him has led to a pretty clear understanding of the succession of the faunas in the district. It has been well understood that the lower lands of the region were underlain by rocks which could be referred without question to the upper layers of the Chemung formation but the strata capping the hills of the southern portion of the area have been variously referred to the Devonic and in part to the lowest beds of the Carbonic. The vagueness of this reference and the want of any recognized line of division between accepted Devonic and supposed Carbonic has been due partly to lack of requisite study and partly to the gradual and undisturbed succession of sedimentation. Between what has heretofore been supposed to be Carbonic (without taking into account any more exact denomination of the horizon) and the recognized Chemung is a series of beds which has been usually termed Catskill and in part so represented on the geologic maps of the state. One of the direct purposes of this work was to determine the value of these beds over an interval where a passage from one of the great paleozoic systems into another was clearly to be looked for. That there is no Catskill sedimentation here in the true meaning of the word, i. e. Catskill in the sense of implying estuarine sedimentation with distinctive organisms of fresh or brackish water habit such as occur in the typical section of eastern New York, is made quite probable. In a general way the section of sediments from north to south across this sheet

is represented by the accompanying diagram where the strata are numbered from top to bottom by the figures 1-13 inclusive. The region is a country of sandstones and flags with interbedded conglomerates and the nature of these beds is sufficiently explained in the matter on the diagram. It will be noted that in this series there are two well defined and heavy sandstones and two equally conspicuous and heavy conglomerates. The lowest of these sandstone beds is stratum no. 13, the Cuba sandstone. 600 feet above it lies stratum no. 8, the Wolf creek conglomerate. Above the latter 200 feet, is the Mount Hermon or Salamanca conglomerate, no. 6, and from there the section rises about 200 feet to the Olean conglomerate, no. 2; the highest sediment in the series being the calcareous shales lying on the top of the last named conglomerate which has been termed the Olean shale. Intervening between the Wolf creek conglomerate and the Mount Hermon sandstone the beds are red and green shales interbedded with flaggy sands, to which it has been proposed to apply the term Cattaraugus beds. The validity and usefulness of the distinctive term for these strata which represent those at times referred to the Catskill formation because of their red color and doubtless a western continuation of Catskill sedimentation is very clearly indicated by the paleontologic evidence which they have furnished. For the shales above the Mount Hermon sandstone and thence to the base of the Olean conglomerate it has been suggested that still another distinctive term would be required, but it is not clear that stratigraphic evidence would favor such determination. The propriety of the subdivision could be established by the variation in the fossil contents, should this appear to be of



sufficient weight. In the study of the vertical distribution of the fauna of this succession, the following points come out with clearness.

Of these 13 columns no. 8 represents the Wolf creek conglomerate and no. 6 the Mount Hermon conglomerate. It is the former which proves to be the important line of change in the succession of the faunas. It is to be understood that there is no evidence in this undisturbed and unfolded region of any abrupt change by sudden extinction of species or by unexpected invasion from east or west, but the succession has gone on without interruption and it is only at that horizon where a decided change becomes noticeable without the extinction of all preexisting forms.

1 Up to the Wolf creek conglomerate the common Chemung species seem to prevail. For example, Spirifer disjunctus, Athyris angelica, A. cora, Chonetes scitula, Orthis tioga, Orthothetes chemungensis, Productellas of various species, Mytilarea, Nucula bellistriatra, Aviculopectens, Crenipectens, Edmondia, some of the Leptodesmas such as L. potens and var. juvenis, L. mortoni, L. sociale, Pterinopecten, some of the gastropods like Bellerophon maera, Euomphalus hecale, Macrochilina and the Dictyosponges.

2 Some characteristic Chemung species pass this limit. Thus, for example, Spirifer disjunctus, which is usually regarded as an index fossil of upper Devonic time, extends beyond the Wolf creek conglomerate up to and within the shales beneath the Olean conglomerate, becoming however of very rare occurrence in horizons above no. 8. Camarotoechia contracta is recorded from all horizons from the base up to and into the Mount Hermon or Salamanca conglomerate. Such species as these however, of which we have cited the most striking instances, must be looked on in the face of the rest of the evidence as having their value as diagnostic of Devonic time modified by the introduction before their extinction of a

striking number of new forms altogether foreign to deposits of earlier age. They are thus in this sense and for the section we have under consideration, superstitial species, that is, purely survivors which have held their ground in the face of organic modifications and change of physical conditions going on about them.

3 The Wolf creek conglomerate marks the dawn of a number of species. Thus a species of the brachiopods, Oehlertella, not to be distinguished from O. *pleurites* which abounds in the Bedford shales of Ohio, appears here and also in the overlying stratum no. 7. Of the Leptodesmas, L. *orodes* here appears; also *Modiola praecedens* and a considerable number of the Ptychopterias; some are identifiable with previously known species and others appear to be of variant form. With a single doubtful exception all these Ptychopterias appear at this horizon or above it. *Palaeanatina typa* also makes its appearance here. The effect however of this conglomerate in the strata is less marked in this respect as the point of departure of novel forms of the series than as a dividing line in the succession of faunas. We may indicate the contrast in the aspect of the faunas above and below this line by the following columns:

Above base of Wolf creek conglomerate	Below base of Wolf creek conglomerate
Agelacrinus buttsi	
	Athyris angelica
	A. cora
A. polita	
Camarotoechia allegania	
	Chonetes scitula
Oehlertella pleurites	
	Schizophoria 2 sp.
	Productella 5 sp.
	Edmondia 3 sp.
	Leptodesma potens
	" " *var.* juvenis
	" mortoni
	" sociale
	" matheri
	" longispinum
	" protextum
	" spinigerum

Above base of Wolf creek conglomerate	Below base of Wolf creek conglomerate
Leptodesma orodes	
" curvatum	
" maclurii	
" mytiliforme	
	Mytilarca chemungensis
	Nucula bellistriata
Pararca 3 sp.	
Ptychopteria 8 sp.	
Palaeanatina 2 sp.	
Bothriolepis	
	Pterinopecten 2 sp.
Ctenodus	Dictyospongia
Holoptychius	Prismodictya 2 sp.
Gyracanthus	Thysanodictya 2 sp.
Fishes	

It becomes quite clear that a fundamental change has entered on the nature of the fauna with the deposition of the Wolf creek conglomerate and in the species herewith commencing their existence we find a certain well defined aspect of Carbonic life, the presence of which is supplemented by the abrupt disappearance of the leading features of the Chemung fauna. We have made special reference to *Oehlertella pleurites* and have already in another place discussed the characters of the *Agelacrinites buttsi* from the stratum 5 which shows a close affinity to cystids of the early Carbonic. It is to be further noted that the post or supra-Carbonic aspect is indicated by the Ptychopterias and Pararcas rather than a true Devonic though the presence of heraldic forms of these genera in Devonic strata is not to be questioned. Yet here by their profusion they indicate a faunal aspect which is peculiar to this horizon. Attention may be directed to the presence of fish remains which have been found in the red beds of stratum no. 7, and of them some, like *Holoptychius americanus*, may be regarded as suggesting the horizon of the Catskill of eastern New York, while others, Gyracanthus, Ctenodotus and Bothriolepis point with more definiteness to a higher horizon.

THE POTSDAM SANDSTONE OF THE LAKE CHAMPLAIN BASIN

NOTES ON FIELD WORK 1901

WITH MAP

BY GILBERT VAN INGEN

The Potsdam sandstone of northern New York is, in the bibliographic sense, one of the best known members of the geologic column. For many years it was considered the lowest member of the series of sedimentary rocks, and was, as such, supposed to contain the oldest known representatives of organic life. In this relation the description of the formation was given considerable prominence in textbooks and its name became a familiar one to students of natural history. In view of these facts it is a matter of surprise that there is at hand so little definite information regarding the physical and biologic characteristics of this formation, which is in reality the least known element of the sedimentary series of New York. Since the original description of the formation by Emmons in 1837-43 little has been added to our knowledge of it as developed within the boundaries of this state. Logan[1] described with considerable detail the group as developed in its northward extension into Canada and added several items of interest to those noted by Emmons. Walcott[2] gives a few notes on the relations of the Potsdam to the overlying formations in the vicinity of Saratoga and Washington counties. Again in 1891 Walcott briefly describes several sections through the formation along the northern and eastern flanks of the Adirondack mountains, in which are given the thickness of the deposits, general statements on the character of the materials, and in which certain fossiliferous zones are recognized as occurring at horizons in the upper part of the series. Ells, 1894, in a paper on the Potsdam and Beekmantown formations of Quebec and eastern Ontario, describes the transition from the sandstone of the

[1] Geology of Canada. 1863. p. 87-96.

[2] U. S. geol. survey. Bul. 30. 1886. p. 21.

Potsdam to the dolomite of the Beekmantown in southern Canada, and concludes from examination of the stratigraphic and physical evidence that the Potsdam should be considered the base of the Siluric system, instead of the uppermost member of the Cambric. More recently the reports by Cushing on the geology of Clinton county have contained some interesting descriptions of the physical characters of the Potsdam sandstone at several localities on the northeastern slope of the Adirondacks. The reports on the geology of the eastern flanks of the mountains along the shore of Lake Champlain afford little more than descriptions of the areal distribution of the sandstone.

Some descriptions of fossils found in the formation have been published, in nearly all cases however without reference to the particular horizons within the formation from which they were obtained. Walcott's sections are the only descriptions extant in which the fossils are referred to definite horizons in the sections.

The above statements will indicate that up to the present time no systematic attempt has been made to study the formation in its entirety throughout its distribution round the western, northern and eastern slopes of the Adirondacks and as a result the following questions remain entirely or in great part unanswered.

1 What are the relations of the Potsdam to the subjacent formations, whether the latter be of pre-Cambric or lower Cambric age?

2 What are the relations of the Potsdam to the superjacent beds of the lower Champlainic (Siluric) series?

3 Where shall the upper limit of the Potsdam be drawn?

4 What are the physical characters that may serve as a means of distinguishing the lower from the middle and upper portions of the Potsdam sandstone?

5 What are the fossil contents of the Potsdam and may they be grouped to form distinct biologic zones? To what extent are they reliable as a means of subdividing the formation and recognizing the lower, middle and upper portions?

6 The Potsdam sandstone being a litoral deposit, what is its deeper water facies?

At the request of the state paleontologist and with a view to securing information toward a solution of some of the above mentioned problems, field work was commenced in the vicinity of Plattsburg, Clinton co. and extended southward through the towns of Plattsburg, Schuyler Falls, Peru and Ausable, into Chesterfield, Essex co. Special trips were also made to Willsboro and Crown Point, Essex co. in the vicinity of which villages the Potsdam has been described as exposed in close proximity to beds of the overlying Beekmantown series. Northward from Plattsburg the work has been continued into the towns of Beekmantown, Chazy, and Champlain.

The following sections, brief synopses of which are given, have been examined with care.

Valley of the Saranac river from above Cadyville to its mouth at Plattsburg, a distance of 10 miles.

Valley of Salmon river from Peaseleeville to its mouth, 11 miles.

Valley of Little Ausable river from above Peru to its mouth, 7 miles.

Valley of Dry Mill brook near Valcour, 3 miles.

Valley of Ausable river from above Keeseville, through Ausable chasm, about 4 miles.

Valley of Boquet river at Willsboro from village to lake and along lake shore, total 5 miles.

Railroad cut along D. & H. track at Burdick's crossing north of Crown Point, about 1½ miles.

Synopsis of sections

Saranac river section from near Cadyville to its mouth at Plattsburg, length about 10 miles

General strike of beds north with an easterly dip of from 5°–10°. Direction of section easterly. Formations Potsdam to Trenton.

This section is described somewhat in detail as it serves as typical of the middle and upper portions of the Potsdam formation of this vicinity.

The lowest beds, 125–B1, of the sandstone are at the Ellis dam on the Saranac river about 1 mile above Cadyville, from which point the sandstone is exposed at intervals down the river for a distance of 2 miles to a point below the mill at Kent Falls, where the highest layer, 125–A13, of the Potsdam in this section is seen dipping into the river. Below this latter point the next outcrop of rock is of lower Beekmantown horizon, 127–B1 to 3, at Treadwell's mill, 5 miles down the river. The intervening space of 5 miles is occupied by drift deposits and it is impossible to determine how much of the area is underlain by Potsdam sandstone and how much by the Beekmantown beds. Still farther down the river, 2¼ miles, the Chazy limestone, 127–A4, outcrops in the river bed with the same general easterly dip. A short distance beyond the Chazy outcrops the Trenton limestone appears in the stream and continues to the lake shore. Throughout the entire section the strike and dip has little variation; the strike changing from N 15° W to N 15° E, and the dip from 5° to 10° degrees easterly. There is no evidence of faulting to increase the apparent thickness of the deposits by duplication of beds. Computing from the length of section, strike and dip, and difference in altitude between the exposure of lowest layer and that of highest layer, we obtain from the Potsdam an estimated thickness of 1150 feet, of which amount the upper 350 feet is fossiliferous.

The lower portions of the formation as seen in this section are of light color; generally gray, with variations to yellowish and bluish gray and occasionally pink tints. The material is quartz sand, well cemented with silicious cement, the grains being both angular and somewhat rounded and varying in size from ½–2mm, with grains of 4 mm diameter on the surfaces of some layers. Many layers contain a considerable admixture of small grains of partly kaolinized feldspar. The layers vary in thickness from 6–24 inches and are as a rule quite compact. Ripple-marks are common on the surfaces of beds and cross-bedding is seen in nearly all layers. A few layers have thin pebbles of shaly material on their upper surfaces, but no

shale pebbles were seen embedded in the midst of layers in this portion of the section. No traces of fossils were found.

This description applies to the rock as exposed at the Ellis dam and just below "Mill C" of the International paper co., 1½ miles down the river, and also to the lower part of the section at Kent Falls, 125–A1.

The upper and fossiliferous portion of the sandstone in this section as seen at Kent Falls, 125–A2 to 13, differs in several important respects from the lower barren portion. The upper part has many layers of thinly bedded, greenish, argillaceous sandstone with shaly partings, on which are fucoids and worm trails. Other layers contain pebbles of shale and dolomite and in these layers are usually found the fossils, which consist of trilobites, brachiopods and gastropods. These upper layers are also wanting in feldspar. The sand grains of which they are made up are markedly rounder, and as a rule the cementation is not so thorough as it is in the lower beds. Heavy beds of compact, even grained, sandstone are less frequent than below.

The uppermost layer of this section is a heavy bed, 10 feet thick, of white, granular, quartz sandstone, with ripple-marked surface, and cross-bedded section. Its appearance is totally different from the heavy beds of the lower portion, its grains being slightly larger, more rounded, and less closely cemented, so that the rock crumbles readily under the blow of a hammer.

Synopsis of the Kent Falls section to show order of fossiliferous horizons, from below upward

125-A1	Barren sandstone	30 feet
125-A2	Irregularly bedded sandstone, shale partings; Lingulella and Obolella	5 feet
125-A3	Barren sandstone	25 feet
125-A4	Bluish sandstone thinly laminated; Lingulella abundant	5 feet
125-A5	Heavy sandstone; Scolithus linearis abundant	3 feet

125-A6 Sandstone in irregular layers; some heavy and compact, others thin, irregular, and shaly; all containing Lingulella in abundance and Obolella. Shale pebbles frequent on some surfaces, also fucoids — 20 feet

125-A7 Sandstone in thin layers that split readily into thinner laminae. Lingulella, Obolella, Ptychoparia minuta?, Conocephalites verrucosus, in abundance — 4 feet

125-A8 Sandstone thinly bedded and shaly in lower portion, heavy in upper portion; Linguloid fragments in abundance in lower portion — 15 feet

125-A9a Vertical interval unknown — about 70 feet

125-A9b Thinly bedded sandstone with fucoids and ripple-marks — 12 feet

125-A10 Irregularly bedded sandstone with pebbles and cavities; laminae separated by shaly partings; fossils most abundant near middle bed; Conocephalites verrucosus(?), Ptychoparia minuta(?), Lingulella, Obolella, worm borings, fucoids — 4 feet

125-A11 Light colored thinly bedded, coarse grained sandstone, full of cavities due to solution of embedded pebbles; fossils, Trilobites (three species), Ophileta, Platyčeras, Obolella, Lingulella, Scolithus canadensis. This fauna has a Siluric expression in the presence of the two gastropods, Ophileta and Platyceras — 8 feet

125-A2 Vertical interval unknown — 40 feet

125-A13 Granular, white quartz sandstone forming highest bed of this section; no fossils; ripple-marked and cross-bedded.

The Beekmantown dolomite, 127-B1-3, appears first in bed of Saranac river at Treadwell's mill, 5 miles below Kent Falls,

and is exposed at intervals for 1 mile down stream to the Lozier dam, 127-B5. The rock at Treadwell's mill is a gray dolomite with an included 4 foot bed of fine grained black arenaceous shale, but at Fredenburg Falls, 127-B4, and at the Lozier dam, 127, 127-B5, it is a heavy, dark blue-brown dolomite, slightly arenaceous, with numerous geodes of yellow and pink calcite. No traces of fossils were found in any part of it. The shale at Treadwell's mill was carefully searched for Graptolites without finding any.

Salmon river section

The elevated land to the west of Peru and Lapham Mills, and to the southeast of Peaseleeville is due to the resistant character of the heavy beds of the lower portion of the Potsdam sandstone which covers the eastern slope of the gneissoid hill known as Terry mountain. The sandstone has a very thin covering of soil and drift and is exposed along the roads that traverse this region, which is locally known as "The Patent". These outcrops of the lower Potsdam, 129-Ao1, consist of ledges of coarse grained quartz sandstone with a considerable admixture of fresh, nonkaolinized feldspar. In color the rock varies from white to gray, yellow, and red. Ripple-marks and cross-bedding are common. No traces of fossils were found. Owing to the irregularity of the ground it was impossible to measure a section across this region. The general strike is northwest, with a dip of 5° or less to the northeast.

This portion of the sandstone belongs apparently at a much lower horizon in the formation than does that at Ellis dam on Saranac river.

Higher layers of the Potsdam are exposed at the mill dam and at the site of the old forge on the Salmon river at Norrisville, 1½ miles northeast of the exposures of 129-Ao1 on "The Patent".

At Norrisville, white sandstone, 129-Ao, 30 feet thick, is seen in the small gorge of Salmon river. The rock is heavily bedded in layers 2-3 feet thick, with much ripple-marking and cross-bedding, but with neither pebbles nor fossils, and has a diminishing amount of feldspar.

Again at Schuyler Falls, 2 miles down stream to the eastward, the sandstone is exposed in the bed of the river. The rock at this point, 129-A1, is about 50 feet thick; a heavily bedded white and gray quartz sandstone, with some intercalated layers of thinly bedded sandstone. These latter are ripple-marked and cross-bedded, contain some pebbles of green shale, and Lingulella and Obolella, and recall the lowest Lingulella-bearing bed, 125-A2, of the Kent Falls section.

No higher beds of the Potsdam are seen above those at Schuyler Falls; the next exposure being of the Beekmantown, 126-A1, with Ophileta and Lingula fragments, in the river bed at the crossing of the Salmon river road at South Plattsburg, 3 miles to the east.

Little Ausable river section from Peru to mouth of river

At the road-crossing in the village of Peru the Beekmantown dolomite appears in the bed of the river below both the upper and lower dams. From this point the river flows approximately along the strike of the beds to the northeast for 1½ miles to Lapham Mills, where its course changes to southeast and it flows over ledges of Potsdam sandstone.

The sandstone at Lapham Mills, 126-C3, has a thickness of about 50 feet, the exposure extending for ⅓ mile down the river from the railroad bridge, and is in some respects different from that seen at any of the other localities. The rock is generally a coarse sandstone of gray color with many layers of brown and red. These red layers are of great hardness and glassy fracture, and full of large grains of pellucid quartz that often attain a diameter of ½ inch. Ripple-marks and cross-bedding are common. No traces whatever of fossils.

One half mile farther down the river in an easterly direction is another exposure of Potsdam, 126-C2, forming ledges in the river bed. A total thickness of 10 feet is shown. The bedding is very irregular, the layers varying from 1–4 inches in thickness, often with shaly partings. The color ranges from white to gray, greenish, and brown; and the texture from fine to coarse. Some layers contain pebbles of schist and slate that attain sizes of 1–3

inches. These pebbles are in all cases flat like those of a shingle beach on a recent shore. Streaks of coarse grained quartz extend horizontally through some of the finer grained beds. The surfaces of the layers are usually covered by ripple-marks and sections show cross-bedding. No traces of fossils.

To the south, east, northeast, and north of this exposure are outcrops of the gray and blue Beekmantown dolomite. No determinable fossils have been found in any of these dolomites and it is now impossible to place them in any particular division of the series. It is also at present impracticable to determine their relations to the neighboring Potsdam. The strikes and dips of the separate exposures correspond sufficiently to allow the assumption that the two formations are here in their normal order of superposition. Other facts, however, seem to point to a different relation. The outcrops are far apart, ½ mile at least; and only 3 miles to the southward the two formations are faulted against each other. The lithic characters of the sandstone seem also to indicate that instead of belonging in the upper part of the formation it should be placed below any of the known fossiliferous horizons.

Dry Mill brook section in the town of Peru, Clinton co.

Dry Mill brook is a small stream that flows into the Ausable river about 1¾ miles north of the mouth of Ausable chasm. Just west of the crossing of Telegraph street the steel gray Beekmantown dolomite, 150-E6, forms ledges in the field. No fossils occur here.

Farther down the stream at the crossing of Lyon street, 1½ miles to the east, the dolomite, 150-E5, is again seen in the bed of the stream and continues from this point for 350 feet from the road bridge. At this point the dolomite is faulted against the Potsdam by a normal fault with downthrow to the west. To the east the Potsdam extends for a distance of 600 feet, with a thickness of 20 feet. The Potsdam here is a coarse sandstone of dark color with some layers that contain black pebbles, and a few thin layers of gray arenaceous shale. No fossils were found in it. Its horizon is unknown.

Port Kent

On the shore of Lake Champlain at Port Kent is a small exposure of the Potsdam sandstone, 124-A1. It is almost 1 mile north of the anorthosite of Trembleau mountain which juts out for some distance into the lake south of Port Kent station. The rock here is 20 feet thick and consists of heavy and thinly bedded layers of white and gray sandstone, some of which contain thin seams of black pebbles. Ripple-marks are common. No fossils. The rock is much broken by joints and the layers are bent; indications of proximity to a line of disturbance. These beds do not belong to the basal portion of the formation, and must be separated from the anorthosite by a fault.

Ausable river section from Keeseville through Ausable chasm

Near the road 1 mile west of Keeseville, just beyond the race-track, the base of the Potsdam sandstone, 150-E2, is seen lying in a depression between two ridges of anorthosite. The actual basal contact of the sandstone can not be seen. This locality was described in considerable detail by Cushing[1] in his report on Clinton county. The rock is here a coarse conglomerate of red sandstone containing gneissic fragments at the base, overlain by red sandstone of finer grain. The rock throughout the entire exposure contains a large amount of feldspar. Across the strike to the southeast the nearest exposure of the sandstone is on the bank of the Ausable river, about ½ mile above Keeseville, where it, 150-B1, outcrops in the vicinity of a boss of anorthosite on the right bank. This outcrop was mentioned by Walcott (1891, p. 343), and was evidently considered by him the basal portion of the sandstone. In reality it is an exposure along a fault which separates it from the anorthosite, and the rock here belongs to a horizon quite well up in the formation though just how far it is impossible to say.

From this point the sandstone is exposed at intervals for 1¾ miles to the dam of the pulp mill at Alice Falls, a short distance above the head of the Ausable chasm. Throughout this distance the beds exposed, 150-B1 to 7, are of the same character as those of the lower portion, 125-B1 to 2, and A1, of the

[1] N. Y. state geol. 15th an. rep't 1895. p. 548.

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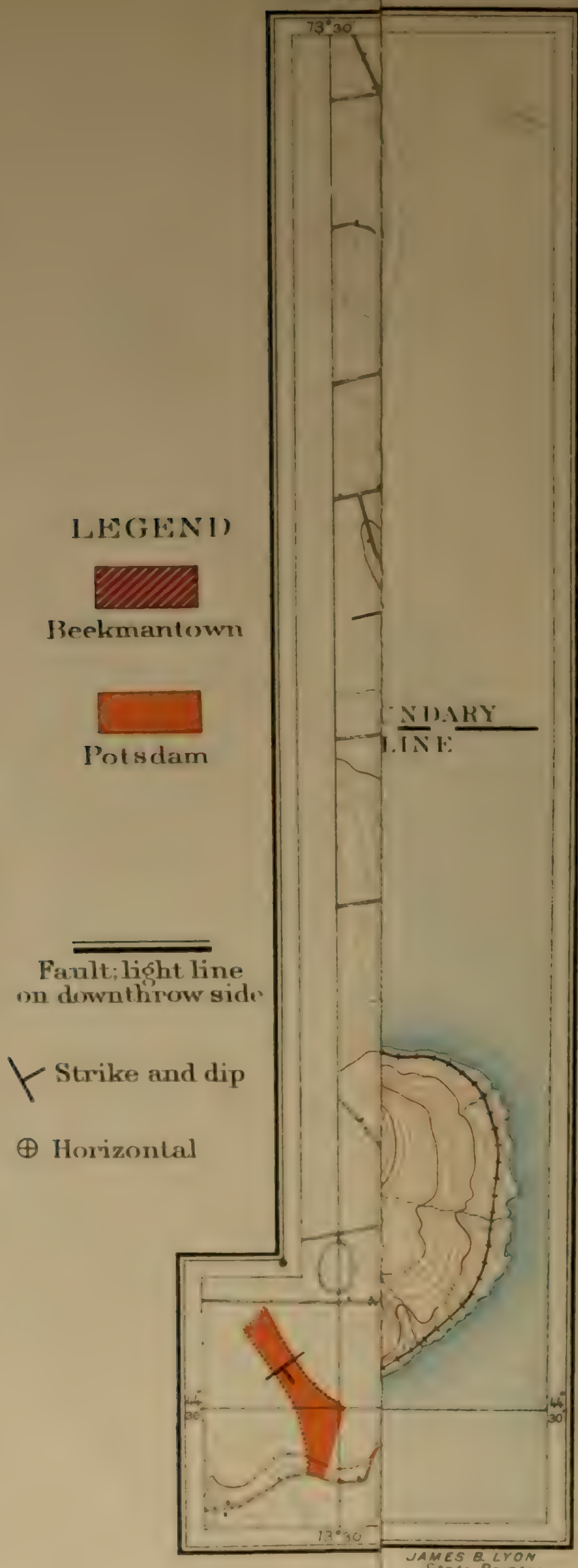

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Saranac river section. The total thickness is not determinable as the outcrops are not continuous and dip faults of considerable displacement are known to traverse the region. The minimum thickness is 60 feet which is the hight of the rocky bank on the south side of the Alice Falls fault.

Below the Alice Falls fault the exposures of the sandstone are practically continuous through the chasm.

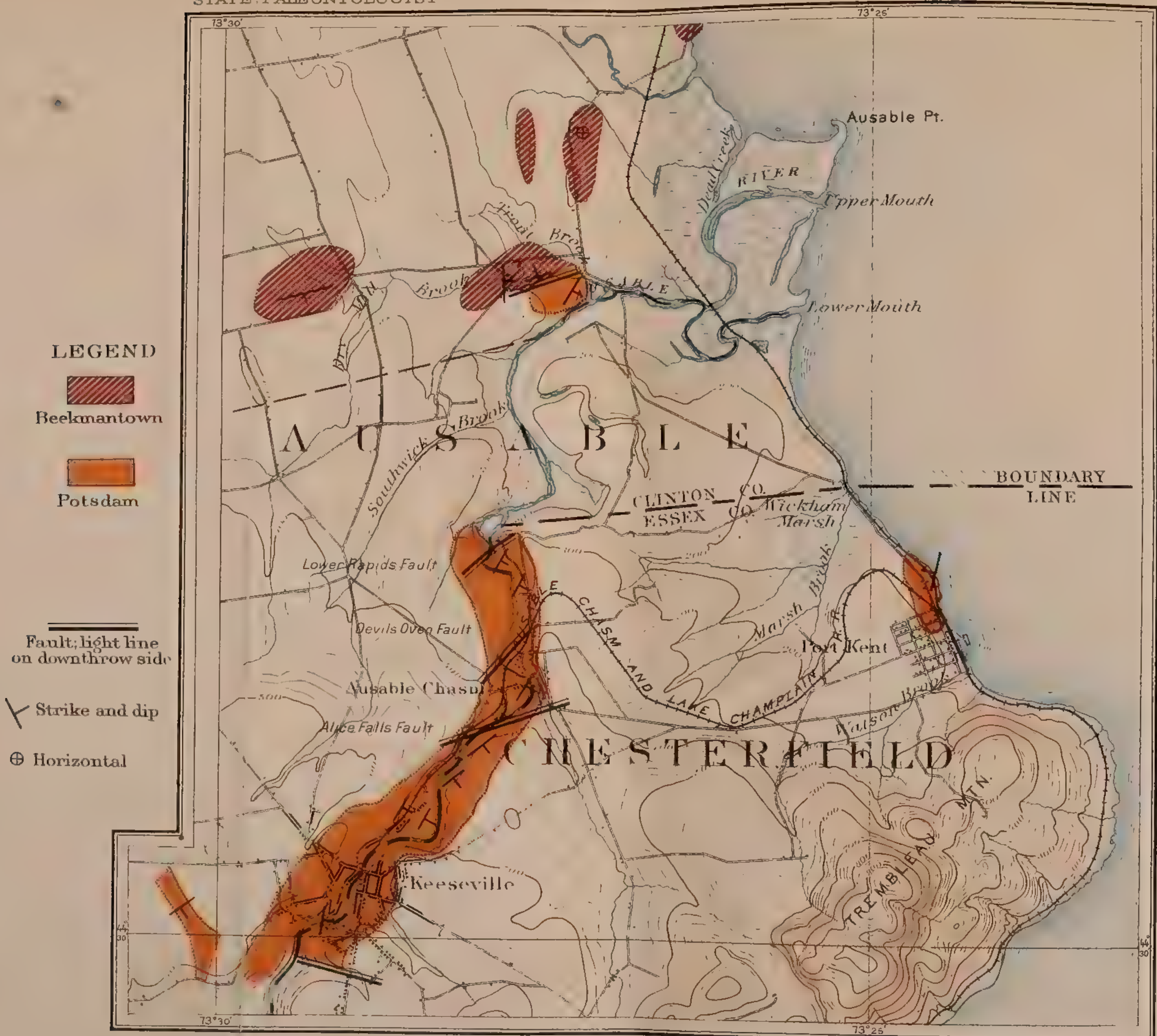
The Keeseville region, as already indicated, is one of tilted fault blocks; the major faults having a direction of about n. 30° e., while the minor faults trend north and south. The close resemblance of the layers throughout the unfossiliferous portion of the sandstone series caused considerable difficulty in the determination of the amount of displacement of the different faults and led to the exclusion, from the total estimate of thickness, of those beds the exact position of which could not be satisfactorily established.

The section of the chasm is through three blocks of sandstone of which the middle block has been dropped down between the north and the south blocks.

The north block with a thickness of 50 feet is of uncertain relation to the other two, so its thickness has been excluded from the total estimate.

The south block extending from Devil's Oven to Alice Falls has a thickness of at least 210 feet. The rock of this block is gray and white sandstone in layers of 2 inches to 3 feet thickness. Ripple-marks and cross-bedding are common. The only fossils found in the layers of this block were tracks of Climactichnites wilsoni which range through 10 feet of ripple-marked layers at a horizon about 90 feet below the top of the block. These layers are exposed at the top of the Birmingham fall at the head of the chasm.

The middle block with the highest beds of this section furnished the layers containing brachiopods, trilobites and gastropods. The thickness of this block as exposed to view is 245 feet. The lowest fossiliferous horizon is at 110 feet from the bottom of the block. This is a sandstone containing pebbles of



JAMES B. LYON
State Printer

PORTION OF S. E. CLINTON AND N. E. ESSEX COUNTIES
SHOWING EXPOSURES OF POTSDAM AND BEEKMANTOWN STRATA
G. VAN INGEN. 1901

Scale $\frac{1}{62,500}$

Contour Interval 20 feet

Datum is mean Sea level

dolomite and shale and the shells of Obolella prima and Hyolithes primordialis (?).

Above the Hyolithes bed is a band of irregularly bedded sandstone limited above and below by bands of greenish argillaceous sandstone, and containing pebbles of brown shale and dolomite. This is the zone of Ptychoparia minuta and Conocephalites verrucosus, and holds, besides these species, Lingulepis minima, Lingulella acuminata, Obolella prima.

Above this zone Lingulella and Obolella occur at frequent intervals throughout 90 feet of the section to within 50 feet of the top. No other trilobite-bearing bed, and no gastropods were found at higher horizons in this section and we are led to think that the highest horizon of this Ausable section is below that of the Ophileta bed of the Potsdam at Kent Falls.

The total estimate of the thickness of the formation at this section must fall considerably below its actual thickness which probably will never be determined because of frequent and profound faulting. The measured thickness is at least 455 feet, of which a lower portion, 210 feet, is in the south block, and a higher portion of 245 feet in the middle block. Of this thickness the upper 110 feet contains the typical Potsdam fauna, without any indications of Siluric relationships. To this total may be added 15 feet, the thickness of the basal beds west of Keeseville, which brings the measured section, with exclusion of all doubtful beds, up to 470 feet.

Willsboro section

The Potsdam sandstone has been reported by J. F. Kemp and the late T. G. White (1894), as occurring in close proximity to the Beekmantown in the valley of the Bouquet river at the village of Willsboro, and on the shore of Lake Champlain near the mouth of the river. The exposures mentioned by the above authors were examined with the result that all the rock cropping out in the river near the village proves to belong within the limits of the Beekmantown series. Down the river, below the

village, this rock is exposed to the mouth of the river. Thence along the lake shore the Beekmantown is exposed in continuous outcrop for $\frac{3}{4}$ mile to the north side of Green bay where it is faulted against the Potsdam sandstone. From this point the Potsdam extends in continuous ledges along the shore for a mile northward to Flat Rock point, which point is incorrectly marked Jones point on the Willsboro sheet of the U. S. geological survey topographic maps.

The thickness of the Potsdam shown here is about 135 feet. The rock is in heavy and thin beds, many layers containing pebbles of shale which on exposure to the atmosphere result in the formation of cavities. Thin layers of greenish arenaceous shale are common. About the middle of the section is a layer, 152-A3, containing Lingulella and Obolella in abundance. No trilobites were seen.

This section seems to be about equivalent with the lower portion of the Kent Falls section.

Crown Point section

A section was examined along the track of the D. & H. R. R. near Burdick's crossing $1\frac{1}{2}$ miles north of Crown Point with the hope of finding some trace of the Potsdam sandstone beneath the lower layers of the Beekmantown. The search proved vain so far as finding the Potsdam was concerned, though the lower portions of the dolomite were found to be arenaceous. The section is 130 feet thick, with Ophileta toward the top of the series. An interesting intra-formational breccia occurs in the lower part of the section and chert beds toward the middle.

Summary of results

The area covered by the sections above described is of small extent when compared with that over which the Potsdam sandstone forms the surface rock to the north and northwest; the results obtained can, accordingly, have little more than provincial value and the conclusions drawn must be of a tentative nature till such time as they may be confirmed after field work over the adjoining districts. They will, however, serve to in-

dicate the lines along which future investigation should be carried on. It may be stated that a good beginning has been made toward the acquirement of a more precise knowledge of the Potsdam sandstone. The results are arranged in sequence under the numbers of the questions on p. 530 and p. 531 at the beginning of the report.

1 The base of the Potsdam has been seen to rest on the irregular surface of the pre-Cambric rocks, with a nonconformable contact, the nature of the contact being such as to indicate a period of long continued erosion. It is of interest to note that in some cases the materials composing the basal conglomerate have been transported from considerable distances and contain no fragments of the subjacent rock of the immediate vicinity. Such an instance is afforded by our basal sandstone, 150-E2, west of Keeseville, a good description of which has been already published by Cushing.

No formations of Cambric age have been found below the Potsdam in the area covered by this report. Certain hypotheses suggested by megascopic examination of the pebbles contained in many layers of the Potsdam can not be discussed till careful microscopic examinations have been made.

2 A possible indication of Ordovician relationship may be afforded by the presence of the genus Ophileta with Platyceras in the upper part of the Kent Falls section. More extensive collections should be made at this point.

In the area under discussion the transition beds between the Potsdam and Beekmantown are absent, both by cutting out along fault lines and by glacial erosion, drift-filled valleys extending parallel to the strike of the formation at those horizons where should be found the transition beds. Farther north in the towns of Champlain and Chazy where the strike is at right angles to the direction of movement of the continental glacier these softer beds of the uppermost Potsdam are exposed to view. They prove to change by slow gradations from sandstones with thin intercalated dolomites, through sandstones with thicker dolomites, finally merging into dolomites with

intercalated sandstone layers and eventually into the pure dolomites of the Beekmantown series. These facts are reserved for more detailed discussion in a future report.

3 No evidence obtained.

4 Certain physical characters have been found to be more characteristic of one portion of the formation than of another, and to some extent are useful as means of recognizing the different horizons.

The presence of feldspar grains appears to be restricted to the lower portion; if the feldspar be accompanied by other minerals, as magnetite, it may be taken for granted that the base of the formation is near at hand. Red and brown are more usually the colors of the lowermost portion. Coarseness of materials with little sorting of the grains according to sizes are also characteristic of this portion.

The middle portion of the sandstone is made up of well sorted materials, of finer grain, compactly cemented, and of white, steel gray, or yellowish color, with very little or no feldspathic content. The grains of sand are both angular and rounded with the former predominating. The layers are more regular though their surfaces are ripple-marked, and in section they are seen to be almost universally cross bedded. Pebbles are found on the surfaces of some layers of the middle portion, but unlike those of the upper portion they seem to have been of soft mud derived by erosion of contemporaneous sediments, cast on the beach at times of rough water and flattened and squeezed out by the subsequent pressure and consolidation of the superimposed sand deposits.

The upper portion of the formation has frequent beds of irregular laminated sandstone with partings of greenish arenaceous shale. The shale surfaces are covered with fucoids and worm trails. Pebbles of shale and dolomite, which were hardened before the time of their entombment, are found embedded in the sandstone layers, and their disintegration causes cavities to form in the layers containing them. The

dolomite pebbles become more abundant toward the upper horizons. Dolomite also occurs in thin beds intercalated between the layers of sandstone toward the higher levels, and in the uppermost horizons, as already mentioned under heading 2, gradually crowds out the sandstone. In the upper levels frequent beds are composed of nicely rounded grains of clear quartz with little cement, that crumble to a sugary powder under the hammer. Rounded grains of quartz of a slightly larger size occasionally cover the upper surface of a layer of finer grained sandstone, and being without cement, they stand out in relief above the surface with an appearance of having been sprinkled from a pepper pot. In other cases aggregations of noncemented grains have been found embedded within layers of heavy though porous beds, as in the case of the Hyolithes bed, 150–A3, in the Ausable chasm.

5 No fossils have been recognized in the lower portions of the formation. The middle portion has afforded only the Climactichnites tracks at the Birmingham bridge, and numerous irregular, unidentified worm borings and trails.

The upper portion of the formation holds fossils through a series of beds aggregating at least 350 feet in thickness. We have at present no evidence on the position of these fossiliferous beds in relation to the actual top of the formation. The list of fossils includes: trilobites, four species; brachiopods, three species; gastropods, three species; annelids, two species, and several undeterminable burrows and trails; fucoids, several; tracks, one species of Climactichnites.

To some extent these fossils may be arranged in zones. Such arrangement can only be tentative and will certainly need readjustment with the extension of the field work over a larger area. Two species of brachiopods, Lingulella acuminata and Obolella prima, seem to occur throughout the entire range of the fossiliferous horizons, as do also the fucoids and many worm trails and branching burrows.

Such zones as can be distinguished are arranged in the following sequence, "a" being the lowest.

a Climactichnites wilsoni Logan; lowest zone in midst of middle portion of sandstone.

b Hyolithes primordialis (?), Lingulella acuminata Conrad, Obolella prima Conrad.

b Scolithus linearis Hall; at Kent Falls only.

c Lingulepis minima Whitfield, Lingulella acuminata Conrad, Obolella prima Conrad, Ptychoparia minuta Whitfield, Conocephalites verrucosus Whitfield.

d Lingulella, Obolella, Conocephalites verrucosus, Ptychoparia small, trilobite with broad cheek, Ophileta compacta Salter (?), Platyceras, Scolithus canadensis Billings.

e Scolithus canadensis in abundance on the upper surfaces of sandstone layers of the transition beds in the uppermost portion of the formation. These uppermost layers have up to the present yielded no other fossils than this worm burrow.

6 No answer can at present be given to this question. Some suggestive evidence has been derived from the pebbles included in the layers of sandstone at various horizons in the formation. It is, however, of such disconnected character and meager amount as to warrant its exclusion from the present discussion.

THE GRAPTOLITE (LEVIS) FACIES OF THE BEEKMANTOWN FORMATION IN RENSSELAER COUNTY N. Y.

BY RUDOLF RUEDEMANN

La masse schisteuse de la vallée de l'Hudson, renfermant de nombreux graptolites, l'existence de ces fossiles sur l'horizon de la faune primordiale serait un fait particulier au continent americain et digne de la plus grande attention. Il resterait à etablir les relations, soit paléontologiques, soit stratigraphiques, entre ces graptolites de la vallée de l'Hudson et ceux de la Pointe Lévis, près Quebec.

BARRANDE. 1862

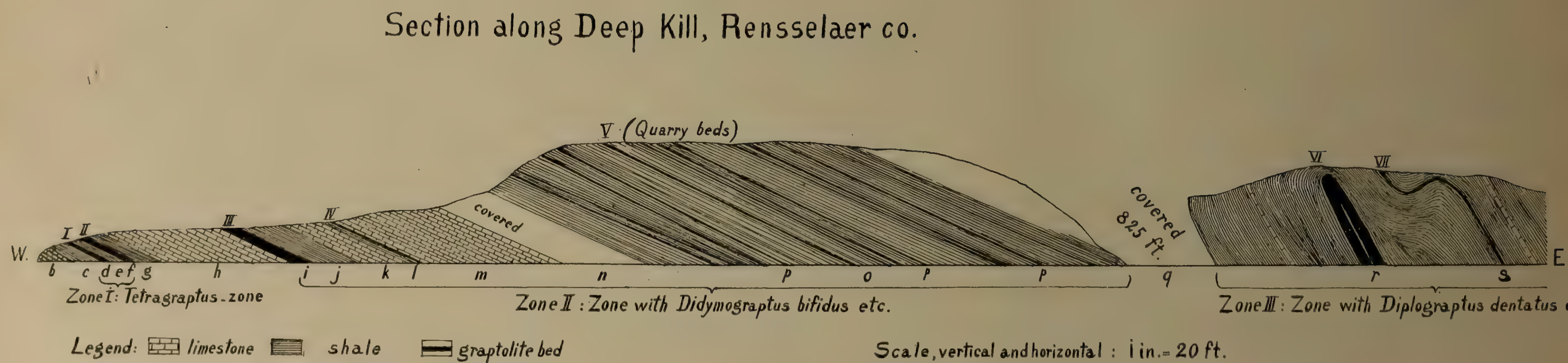
DESCRIPTION OF THE EXPOSURE

The section described in this paper is exposed along the Deep kill, a small eastern tributary of the Hudson river, and begins about a quarter of a mile east of the small settlement known as Grant Hollow in the northwestern part of Rensselaer county.

a In ascending the Deep kill valley from Grant Hollow, the first exposure is a small outcrop in the south bank of a few feet of deep black mudstone giving conchoidal fracture. This rock has furnished no fossils. Another outcrop, where are exposed somewhat contorted dark gray, sandy, thinly bedded shales with a few intercalations of argillaceous sandstone, is 30 feet farther up. These strata also proved to be barren of organisms.

The continuous section begins 700 feet farther east, on the north side of the creek. The beds of this exposure are, in contrast to those met with farther up and down the creek, free from flexures and dip uniformly N 116° E at an angle of 24°. It is apparent that the extremely heavy bedded, hard silicious beds and the limestones prevailing in this section protected the shales from being thrown into the many small, closely packed folds so characteristic of the softer and more pliable terranes of the region. There is no cleavage in these beds; and the slickensides, which often run subparallel to the bedding planes and obliterate or at least distort all organic remains in so many outcrops of the Trenton, Utica and Lorraine shales in the Hudson river region, are frequent only where the heavy quartzose banks have slipped along the thin shale partings. To the absence of these antagonists of the paleontologist the beautiful

Plate 2


Section along Deep Kill, Rensselaer co.
V (Quarry beds)
I
II
III
IV
VI
VII
covered
covered
825 ft.
W.
E
b c d e f g h i j k l m n p o p p q r s
Zone I: Tetragraptus-zone
Zone II: Zone with Didymograptus bifidus etc.
Zone III: Zone with Diplograptus dentatus
Legend: limestone
shale
graptolite bed
Scale, vertical and horizontal: 1 in. = 20 ft.

preservation of the graptolites in the Deep kill beds is largely due.

b At the base of the section (*see* diagram) are found 4 feet 9 inches of rock, consisting of rather regular alternations of thin limestones, with thinner layers of shale. These beds still show some irregularity of tilting. The limestone as well as the shale appears to be quite barren of organisms.

c Then follows a stratum, 2 feet 8 inches, consisting of rapidly alternating gray to reddish gray coarse grained sand-shales and dark, finer grained, highly silicious beds. The lower layers of the latter contain numerous small, angular pebbles of limestone and black hornstone in such quantities that these appear brecciated.

d This stratum is overlain by 8 inches of thin, dark greenish gray, hard silicious bands with thin intercalations of black shale. The latter contain graptolites in great number. This bed we connote as *graptolite bed 1*.

e Thin bedded shales and silicious layers; 1 foot 8 inches. The lowest is a thin limestone band; another is found near the middle. The silicious bands change in places to grits and breccias as in stratum *c*. Fossils seem to be absent.

f Greenish gray, hard silicious layers and intercalated deep black shales, forming a stratum which lithologically is like stratum *d;* 1 foot 9 inches. Like the latter, it carries graptolites in great profusion. Indeed, this bed has proved the richest of all in these fossils, and its graptolites are in the best state of preservation. It is here termed *graptolite bed 2*. The greenish quartzose bands are perforated in all directions by worm tubes and are covered by carbonaceous blotches apparently originating from seaweeds.

g Thin bedded, very hard, gray to black silicious beds, 2 feet 9 inches, overlie these graptolite shales. They are not separated by shale partings, and show no traces of organic life.

h Thin bedded, dark gray, hard limestone, with no indications of organisms but worm tubes; 14 feet 3 inches. The layers possess very uneven surfaces, as if deposited in turbulent water,

and also inclose a few intercalations of coarse arenaceous beds, of breccia bands and of shale. The last contains no graptolites and differs from the graptolite shale by its lighter color, coarser texture and more abundant arenaceous element.

i Greenish gray silicious beds with intercalated soft carbonaceous shale, the latter containing a considerable graptolite fauna; 2 feet. The shale is a little more sandy than that of the preceding graptolite beds; and the fauna, as shown by the lists of fossils, is so different that it heralds the appearance of a new zone. This is *graptolite bed 3*.

j Regular alternations of greenish gray, thinly laminated silicious layers and dark gray sandy shales; 5 feet 5 inches; no fossils. A thin seam of bluish black pyritiferous shale with a few graptolites was observed both near the bottom and top of the layers. The graptolites do nct differ from those of bed 3.

k Dark gray limestone layers; 5 feet 9 inches. The limestone layers are thin, partly evenly bedded, partly exhibiting interlocking, narrowly undulating surfaces, very similar to those of the European triassic "Wellenkalk." There is here also a breccia 5 inches thick, with coarse sand as cement. The thin, shaly partings between the limestone layers contain no graptolites.

l Alternations of greenish silicious beds and black shales, with a 4 inch limestone breccia in the middle; 16 inches. Graptolites occur sparingly and in poor state of preservation in the shale. This *graptolite bed 4* has the characteristic species in common with bed 3.

m Limestones which exhibit the undulating character noted above still more strikingly; 16 feet. The thin shale partings between the limestone layers, as in all other limestone strata of the section, are destitute of graptolites.

n Covered; 8 feet 9 inches.

o This short break in the section is followed by the large exposure in the quarry lately opened to obtain the material for the construction of the dam of the Lansingburg waterworks.

There are exposed here 52 feet of hard, quartzose, fine grained and thin bedded layers, which however have become consolidated into compact banks averaging 2 to 3 feet in thickness. The thin bedding is indicated by the rapid alternation of darker greenish gray with lighter colored bands. These heavy banks are separated by extremely tenuous partings of carbonaceous shale, which are often densely covered with graptolites, mostly specimens of Phyllograptus. The graptolite layers of the quarry beds are, on the diagram, designated by heavier lines and the letter *p*. They constitute *graptolite bed 5*. By orogenic disturbances which have affected this region the blocks have been slipped along many of the partings and the organisms destroyed. In the silicious layers only worm tubes were noticed.

q Here ends the practically continuous section of the lower and middle graptolite zones, and for a distance of about 825 feet (figure obtained by pacing) no further exposures could be found.

r Then follows the large but temporary exposure afforded by the cutting into the north bank of the creek for the purpose of securing the north end of the dam. The length of this section was 135 feet. The prevailing rock of the exposure was greenish gray quartzite, similar to that of the quarry beds, but less compact and softer, with some brecciated layers and several thin bands of gray limestone interbedded with the greenish rocks. All these strata were however contorted in the manner mentioned before.

Two graptolite beds were found in this part of the section. The first (*bed 6*), 39 feet from the west end of the cut, forms the nucleus of a narrow steep fold consisting of 6 feet of a compact mud rock. As the bed is folded on itself, the actual thickness of the layer is 3 feet. 30 feet farther east 2 feet of a soft black graptolite shale were found (*graptolite bed 7*). On account of the disturbed position of the beds, the exact distance between the graptolite beds and the total thickness of the beds exposed could not be ascertained satisfactorily. The

great majority of the organic remains were obtained from the huge pile of rock material taken from the cutting and dumped a little farther down the creek.

The list of organisms collected in this last section will demonstrate that they belong to another and entirely different fauna, which represents a zone that in Europe has been found to succeed that of the quarry beds. It is, hence, safe to assume that the beds in the cut are a part of a terrane which overlies those exposed in the lower continuous section. In the latter there are exposed upward of 123 feet of rock. The beds in the dam cut, which is 135 feet long, may have reached 60 feet in thickness. Hence, even if the beds in the covered interval of 825 feet (which, taking account of the dip, would represent an approximate maximum of 336 feet) were repeatedly folded on themselves, they would easily reach 100 feet in thickness, and the rocks of all three zones, from the west to the east end of the section must have attained a total thickness of 200 to 300 feet.

The investigations carried on by Prof. T. Nelson Dale in the slate belt of Vermont and eastern New York in the region to the north of the Deep kill have shown the occurrence in a number of localities of "dark gray calcareous or very quartzose, finely bedded shales or black shales with thin limestone beds immediately overlying the ferruginous quartzite" which is considered of Cambric age.[1] It is added that these "are easily overlooked on account of their inconspicuous characteristics and their inconsiderable thickness." In the table facing p. 178, the latter is given as 35+ feet. Graptolites found in these shales were referred to Dr Gurley and determined as follows: Bryograptus, Dichograptus, Callograptus salteri? *cf.* Dendrograptus *sp.* and Dictyonema flabelliforme, and it was concluded that "several of these are regarded as probably of Calciferous age." The genera identified indicate that either the beds observed in these localities may be identical with those of one of the Deep kill zones,

[1] Slate belt of eastern New York and western Vermont. 1899. p.185.

viz, the lowest, which then would appear to rest directly on Cambric beds; or that they may, as suggested by the reported identification of Dictyonema flabelliforme, belong to an upper Cambric or transitional zone, and that the Cambric may, therefore, be also represented in this slate belt by graptolite shales. The fact that the middle and upper zones found at the Deep kill seem to be absent in the outcrops referred to by Dale, may also account for the small thickness of the terrane reported by that investigator, as compared with that found at the Deep kill.

A striking feature of the Deep kill section, and one worthy of special notice, on account of the still contested nature of the habitat of the graptolites, is the regular periodic succession of the rocks associated with the black graptolite shales within the two lower zones. To demonstrate these cycles of deposition, the list of the beds is given in a more comprehensive form.

b *limestones* with shaly intercalations
c sandy shales and grits
d greenish silicious shale and black *graptolite shale*
e thin bedded shales, grits and *limestone*
f greenish silicious shale and black *graptolite shale*
g greenish silicious shale
h *limestone*
i greenish silicious beds and black *graptolite shale*
j greenish silicious beds and sandy shales
k *limestone*
l greenish silicious beds and black *graptolite shale*
m *limestone*
n covered
o greenish silicious beds and black *graptolite shale*

It will be noticed that the deep black, soft graptolitiferous mud shales are always inclosed in greenish gray, very hard, thin bedded, more quartzose layers, and that between two periods of deposition of these there is always intercalated one of thin bedded, barren limestone. This alternation is presented five times in the section.

It has also been observed at other graptolite localities, for example, the Normans kill shale on the north side of Mt Moreno near Hudson, that the graptolite-bearing shale was enveloped in greenish, hard silicious beds. The close stratigraphic connection existing between these greenish and the graptolite shales, and the absence of graptolites from the lithologically similar black shale partings of the calcareous layers indicate that both the former originated under closely similar conditions. It suggests itself that the only change in the physical conditions was in the swiftness of the current, the silicious beds being deposited in a current which carried more material, while a slackening of the current allowed the slow deposition of the fine argillaceous and carbonaceous mud which entombed the graptolitic detritus. That the latter, in most of the Deep kill beds, can not have been exposed to any turbulent wave or current action, is clearly evinced by the retention of the most delicate parts like the hydrocaulus. It is further clear that the graptolites did not live continuously on the bottom where they are now found, for they appear only intermittently and then in vast multitudes and always in different associations. The aspect of the paper-thin seams changes kaleidoscopically from seam to seam; and often a surface will present nothing but the spawn or only a certain growth stage of a single species. These conditions of deposition, and similar ones in the Trenton and Utica zones argue that the fauna was, from time to time, carried into this coastal region of the sea from an outside and presumably pelagic region.

The limestones which form considerable banks between the graptolite beds are evidently not direct organic deposits or shell heaps, but were either derived from the abrasion of a calcareous coast which furnished the fine calcareous mud, or were direct chemical deposits such as are formed wherever decaying organic matter furnishes the necessary carbonate of ammonia to form calcium carbonate out of the gypsum contained in the sea water. As the carbonaceous mud partings between the calcareous layers indicate an oft-repeated interruption of the

process of calcareous sedimentation, it is more probable that the calcareous mud was derived from the coast and was also brought into that neighborhood by the motion of the water. In taking account of all observed changes of deposition in the Deep kill section, it is fairly safe to conclude that an alteration in the direction of the movement of the water caused either the calcareous or the silico-argillaceous mud to be deposited.

The fine grained shaly partings between the beds were formed during a period of quietness; but, while these partings of the limestone beds are barren, those of the silico-argillaceous mud beds are covered with graptolites; hence, at the period when the currents brought the calcareous deposits and during the intervening shorter calms, the higher levels of that part of the sea were free from graptolites, while at the period when the silico-argillaceous mud was brought in, the sea swarmed with them.

In an excellent exposition[1] of the probable conditions of life of the graptolites, Lapworth has concluded that the fine grained black graptolitiferous sediment may have been deposited either in shallow or in deep water and that its formation depended not so much on depth as on the quietness of the water. The conditions under which the Deep kill graptolite beds appear to have been deposited seem in full accordance with this inference, and from the character of the sediments in that section as described above, it also appears that the direction of the flow of the water, which precluded the period of quietness or which continued in the higher levels of the sea must have been on the whole shoreward from the open sea, which latter undoubtedly was the habitat of the graptolites. Thence they came either as holo-planktonic free floating organisms or as pseudo-planktonic, fastened to seaweeds of the character of the recent sargasso, as argued by Lapworth.

The water from which the graptolites were settling was not altogether free of current movement, as is shown by the parallel

[1] Zeitschrift der Deutsch. geol. Gesellschaft. Jahrg. 1897. Heft 2, p. 239 ff.

direction in which the specimens lie in some beds. But it was always a very gentle flow, as otherwise neither the very fine mud nor the graptolites themselves could have been deposited thus.

GRAPTOLITE ZONES OF THE DEEP KILL SECTION

A. Tetragraptus zone

Graptolite bed no. 1

The first graptolite fauna of the section occurs in bed *d* and is characterized by the prevalence of representatives of the genus Didymograptus, notably of Didymograptus patulus, the colonies of which are found in great profusion on every slab from this bed. The entire faunule of bed *d* consists of the following forms:

1	Callograptus salteri *Hall*	rr
2	Bryograptus *sp. nov.*	c
3	Dichograptus octobrachiatus *Hall*	rr
4	Tetragraptus serra *Brong.* (=T. bryonoides *Hall*)	r
5	Tetragraptus bigsbyi *Hall*	c
6	T. fruticosus *Hall*	c
7	T. *sp. nov.*	r
8	Didymograptus nitidus *Hall*	c
9	D. patulus *Hall*	cc
10	Phyllograptus ilicifolius *Hall*	r
11	P. angustifolius *Hall*	rr
12	Dawsonia monodon *Gurley*	c
13	Caryocaris *sp.*	c
14	Small oboloid and linguloid brachiopods	cc
15	Small indet. gastropods	r

Graptolite bed no. 2

The next faunule is that of bed *f*, which is separated from the preceding by only 1 foot 8 inches of barren layers. This graptolite bed, with a thickness of 1 foot 9 inches, proved not only extremely rich in number of species and specimens, but specially valuable on account of the excellent state of preservation of

the latter, which are highly lustrous and clearly had not been exposed to any maceration before becoming embedded. This bed must be regarded as a veritable treasure chamber, as it contains numerous perfect colonies which are neatly spread out on the surfaces of the slabs and retain all parts, the central disk, sicula and virgula; and some species occur in all their growth stages. In one layer, a great number of the specimens are pyritized, specially so the numerous hydrosomas of Phyllograptus ilicifolius and of the dichograptids. This material will allow an investigation into the structure of these forms.

The writer abstains in this publication from describing the numerous forms which are not identifiable with species hitherto known on this continent, partly because time has not yet allowed a satisfactory illustration nor a thorough comparison with related species known from foreign graptolite shales; and partly because a monograph of the graptolites of New York is thought to furnish a more appropriate receptacle for such descriptions.

The following is a list of the species found in graptolite bed 2:[1]

1	Dendrograptus *sp. nov. Hall*	r
2	D. cf. gracilis *Hall*	r
3	Dictyonema *sp. nov.*	r
4	Callograptus salteri *Hall*	r

[1] The peculiarity of most graptolite beds, that the separate layers of the same bed differ in the relative prevalence of certain species and hence in the general aspect of the assemblages, is strongly marked in this; certain layers are nearly covered with specimens of a new Bryograptus, others with those of the various tetragraptids and again others with the branches of dichograptids. Fossil lists of the faunules of these thin layers fail, however, to bring out a difference in their composition, or in the number of species. It appears, therefore, that all these different assemblages lying so close together in the rock, were derived from contemporaneous denizens of the sea. These graptolites either lived together in shoals, or more probably, while slowly settling, became separated according to their size and weight.

If, therefore, a form as Bryograptus *sp. nov.* is listed as extremely common (ccc) this statement does not refer to all layers of the bed, but only to one or to a few.

5	Bryograptus *sp. nov.*	ccc
6	B. kjerulfi *Lapworth*	rr
7	Loganograptus logani *Hall*	ccc
8	Dichograptus octobrachiatus *Hall*	ccc
9	Goniograptus thureaui *McCoy*	cc
10	Goniograptus *sp. nov.*	r
11	Temnograptus *cf.* multiplex *Nicholson*	c
12	Tetragraptus fruticosus *Hall*	cc
13	T. fruticosus *var. nov.*	c
14	T. serra *Brong*	cc
15	T. bigsbyi *Hall*	cc
16	T. quadribrachiatus *Hall*	cc
17	T. *aff.* hicksii *Hopk.*	r
18	T. *sp. nov.*	r
19	T. *sp. nov.*	r
20	Phyllograptus ilicifolius *Hall*	cc
21	P. angustifolius *Hall*	r
22	Didymograptus nitidus *Hall*	c
23	D. patulus *Hall*	cc
24	D. extensus *Hall*	cc
25	D. filiformis *Tullberg*	r
26	D. (Leptograptus) *sp. nov.*	c
27	Dawsonia tridens *Gurley*	c
28	D. monodon *Gurley*	c
29	Caryocaris curvilatus *Gurley*	cc
30	*Cf.* C. oblongus *Gurley*	r
31	Small indet. brachiopods	cc

A comparison of the fauna of graptolite beds 1 and 2 proves that both belong to the same zone. This zone is characterized by the prevalence of species and individuals of the genera Dichograptus, Tetragraptus, Didymograptus and Phyllograptus. Of these the genus Tetragraptus appears with the greatest number of species, and it clearly reaches the acme of its development here. While T. quadribrachiatus and the new species have not been observed to pass into the higher zones,

the other species are represented in the latter only by dwarfed mutations. The term "Tetragraptus zone", which has been proposed for the corresponding zone in the Skiddaw beds of England, appears, therefore, to be also quite appropriate for the American graptolite zone.

Among the species of Didymograptus it is a striking phenomenon that only the forms with horizontally extended branches are present, while the "tuning fork" species, so characteristic of the middle Lower Siluric zones of Europe, are still entirely absent. Goniograptus thureaui also extends into the next zone, but does not there attain the size of its ancestors. The genus Phyllograptus attains its largest size (Ph. typus) and its greatest number of species only in the next horizon.

Nearly all the species of this fauna, which bear Hall's name as that of their author, were described[1] as coming from the "shales of the Quebec group, Point Levis." While Hall in these important papers did not enter on a discussion of the age of the graptolite shales of the Quebec group, he correlated, in the table showing the vertical distribution of the graptolites (*loc. cit.* p. 55), the Quebec group with the Calciferous and Chazy periods, thus placing these graptolite beds in a general way near the base of the Lower Siluric. Nor did he attempt to separate the graptolite fauna of the Quebec group into its constituent zonal faunules, but from the associations which he mentions in the descriptions of the species the presence of two different faunas, that of Point Levis and that of the St Anne river, is clearly apparent. These two faunas were differentiated as the Point Levis zone and the River St Anne zone by Lapworth,[2] and the latter zone, in accordance with the succession established in England, is placed above the former.

Later, the same distinguished investigator of the graptolites studied[3] collections from the lower paleozoic rocks on the south

[1] Geol. sur. Canada. Rep't for 1857; and fig. and descr. Can. org. rem. Decade 2. 1865.

[2] Ann. and mag. nat. hist. 1880. 5th ser. 5:275.

[3] Roy. soc. Canada. Proc. and trans. 1886. 4:167 ff.

side of the St Lawrence river. These contained only the association characteristic of the next higher Deep kill zone, and it was placed provisionally in the Chazy. Lapworth added that there are certainly several zones at Point Levis, and that, by analogy with the English series, he would place the zone last named at about the middle of the series. This conclusion is fully verified by the actual succession of the zones in the Deep kill section.

A very thorough account of the history of the problem of the Quebec terrane has been given by R. W. Ells,[1] accompanied by extensive fossil lists from all outcrops of the Quebec region, prepared by Dr Ami. The succession of the larger divisions of the Quebec terrane is therein clearly set forth. Dr Ells concludes in this paper that the evidence afforded by the stratigraphy and by the graptolites determined by Prof. Lapworth, is sufficient to refer the Sillery rocks (1–4) to the Cambric system, and the Levis beds (5) to the lower Ordovician. He suggests that the term "Levis" be used for the local development of the Calciferous (Beekmantown) terrane about Quebec. These Levis beds measure, according to Logan, about 2000 feet in thickness. As the Deep kill beds contain the greater part, if not all, of the graptolites which have become known from the Levis beds, they represent a southern continuation of the same, or, more exactly speaking, of the graptolite shales contained in the Levis beds; for the conglomerate bands of the Levis region with their interesting fauna, both in the matrix and boulders, are apparently wanting here.

In reviewing Dr Ells's report, Mr Walcott[2] states that in 1889 he found together with Dr Ells the typical Calciferous fauna in the matrix of the conglomerate bands in the Levis beds, while the boulders contain the Potsdam fauna. The mixing of these two large faunas has been the cause of much of the confusion and mystery surrounding for so long a time this part of the Quebec terrane.

[1] Geol. nat. hist. sur. Canada. Rep't 1888. 2d ser. v. 3, pt 2, 12 k ff.
[2] Am. jour. sci. 1890. 3d ser. 39:101 ff.

The results of these investigations leave no doubt that the *Tetragraptus zone of the Deep kill section*, which is identical with one of the Point Levis zones, *is* properly to be regarded as *a graptolite facies of the Beekmantown or Calciferous period.*

No attempt was made by Dr Ells to separate the various graptolite zones of the Levis beds. Later, it was stated by Ami[1] that there exist well marked zones in different portions of the series of the Levis strata, but their separation was not carried out. It is, therefore, evident that the complicated stratigraphic conditions under which the Levis beds are found in the Quebec region do not invite or permit an establishment of the succession of their faunal zones.

An attempt to accomplish this, however, by reference to the well known succession in Europe, has been made by Dr R. Gurley.[2] Dr Gurley states that he had the opportunity of studying two different collections, with different faunas, from the Point Levis shales. One of these, coming from a black shale, with Dichograptus flexilis and Phyllograptus ilicifolius var. as conspicuous members, is termed the *Main Point Levis zone* and tentatively placed in the Lower Calciferous. It is with the fauna of this zone that the assemblage described above as characterizing the lowest beds of the Deep kill section, or those of the Tetragraptus zone, is identical.

Mr G. F. Matthew has reported[3] the occurrence of the zone with Dichograptus logani and Tetragraptus quadribrachiatus, etc. in the St John basin, separated from the Cambric zone of Dictyonema flabelliforme by several hundred feet (175?) of shales whose fauna is unknown. As the other zones seem to be absent in that region, it does not furnish any clue to the stratigraphic relations of the Levis zones.

A more exact determination of the position of this zone in the series of paleozoic formations has been possible in Scandinavia and Great Britain. In England, the graptolite fauna

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[1] Geol. soc. Am. Bul. 1890. 2: 492.

[2] Jour. geol. 1896. v. 4, no. 3, p. 302.

[3] Can. rec. sci. Oct. 1891; p. 3; Nat. hist. soc. Bul. 10, p. 3.

of the lower part of the Skiddaw slates in the Lake district has for a long time been known to have more species in common with that of the Quebec shales than with the other English graptolite faunas. Nicholson and Lapworth described numerous forms from these interesting beds and concluded that the lower Skiddaw slates, or the zone of Tetragraptus bryonoides, corresponds to the principal zone of the Quebec beds, which is the Main Point Levis zone of Gurley. These lower Skiddaw slates they considered as contemporaneous with the lower Arenig, and therefore placed the zone near the base of the lower Siluric.

Lately, the graptolite fauna of the Skiddaw slates has been carefully investigated by Miss G. L. Elles.[1] Miss Elles concludes that the Skiddaw slate fauna, "though it is more closely related to the fauna of the Quebec group of Canada than to that of any English beds, is still more nearly related to the Swedish fauna; for, while of the whole 59 species, 25 are common to the Skiddaw slates and the Quebec, and only 14 common to the Skiddaw slates and the two other English areas, no less than 34 species are common to the beds of Sweden and the Skiddaw slates." The fact of the greater resemblance of the Skiddaw and Swedish faunas can not be held, however, to vitiate the conclusion of the homotaxy of the Quebec or Levis and of the Skiddaw zones; for it is only natural that, in homotaxial beds the English and Swedish faunas which flourished in closely adjoining geographic regions should have more forms in common than the Skiddaw and the far distant Levis faunas. The writer believes that, considering the great difference in relative distances, the great number of forms which are common to the Skiddaw and Levis beds, and which comprise one half of all the Skiddaw species, is as conclusive proof of the homotaxy of these latter beds as the greater number of common species is of the English and Swedish beds. This argument is aided by the consideration that the Levis fauna has not by far been as thoroughly studied as the Skiddaw and Swedish faunas, because

[1] Quar. jour. geol. soc. 1898. 54: 463 ff.

Prof. Hall had not as complete collections at hand as were gathered by the numerous English and Swedish collectors and that nearly all Levis forms were found in the Skiddaw slates; that hence, vice versa, a more thorough investigation of the Levis beds would bring to light still a considerable number of species at present known only in England and Sweden. In fact, the provisional identification of the faunas collected at the Deep kill points already to an increase of the forms common to both continents. Furthermore, it is just these most characteristic forms that are common to the Skiddaw, Swedish and Levis faunas. Finally, the discussion of the next two succeeding graptolite zones of the Deep kill section will show that their succession, and hence most probably also that of the Quebec zones, is identical with that of the Lake district and Scandinavian zones. This parallelism of the succession of the zones can, however, be construed to mean only that these faunas occupied these vast territories contemporaneously and in the same succession.

The complete list of graptolites of the Skiddaw slates given by Miss Elles (*loc. cit.* p. 526-27) indicates that the fauna of the Deep kill zone, here under discussion, *corresponds to a part of the fauna of the middle Skiddaw slates or Arenig.* These middle Skiddaw slates have again been subdivided by Nicholson, Marr[1] and Elles. Miss Elles divides them into the lower Tetragraptus bed, the Dichograptus bed and the upper Tetragraptus bed. As no lists of the faunules of these subdivisions are furnished, a final correlation of the Deep kill Tetragraptus zone with any of these subzones would be inadvisable at present. But the facts that the species of the multiramose dichograptids of the genus Clonograptus,[2] so common in the Main Point Levis beds, are absent in the Deep kill zone and represented by Goniograptus, a type of evidently later development; and that the younger genus

[1] Geol. mag. 1894. 4th ser. 1: 122.

[2] In connection with the peculiar absence of species of Clonograptus may be pointed out the equally peculiar presence of two species of Bryograptus, a distinctly Cambric genus; one of these with a profusion of individuals.

Dichograptus *sensu stricto* is greatly predominant, would indicate that there may exist in the Main Point Levis zone a still older subzone, carrying principally these species of Clonograptus, and which is not exposed in the Deep kill section. The latter subzone would then correspond to the lower Tetragraptus beds, and *this Deep kill subzone to the Dichograptus beds.* This correlation is supported by the fact, that the next Deep kill zone is homotaxial with the upper Tetragraptus beds.

The investigations of Hopkinson and Lapworth[1] have demonstrated that the characteristic fossils of this zone occur also in the Arenig series of St Davids in Wales, of Shelve in West England, and in the Ballantrae terrane, underlying the Moffat series in south Scotland.

The most detailed division of the graptolitiferous beds and the most exact correlation with the limestone facies have been attained in southern Sweden where the paleozoic beds, as a rule, lie horizontal. It is only necessary to cite the names of Linnarsson, Törnquist and Tullberg to indicate the refined division in zones of the Siluric in that country, which now has become common property by its adoption in textbooks.

Linnarsson[2] comprised under the name *lower Graptolite schists* (or *Phyllograptus schists*, as proposed by Dr Törnquist) all the graptolite-bearing strata that lie between the Ceratopyge and Orthoceras limestones. Their fauna consists of the Dichograptidae and their closest ally the Phyllograptidae. He points out that the most abundant species are identical with or representative of those familiar to us in the Skiddaw and Quebec groups, such as Didymograptus patulus, constrictus, indentus, etc., Tetragraptus quadribrachiatus, bryonoides and bigsbyi. There can be, hence, no doubt *that this zone is identical with the lowest Deep kill zone,* called the Tetragraptus zone in this publication.

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[1] *See* specially Ann. and mag. nat. hist. 1879. 5th ser. 2: 4, and Geol. mag. 1889. 3d ser. 6: 20, 59.

[2] Geol. Fören. Förhandl. Stockholm. 1879. no. 8, p. 227 ff.

Tullberg[1] divides F, his Understa etagen, into

a Zone with Phyllograptus *sp.*

b Orthoceras limestone

c Tetragraptus shales (lower Graptolite shales)

d Ceratopyge limestone

The *Tetragraptus zone of the Deep kill section* or the Main Point Levis zone of Gurley, *is homotaxial with Tullberg's zone of the Tetragraptus shales.* As we shall see presently his zone *a*, the *zone with Phyllograptus sp.*, is also represented in the Deep kill section.

In the region of Christiania in *Norway* the presence of the fauna of the Tetragraptus zone has been demonstrated by Kjerulf (his "lower Graptolite shales") and Brögger ("Phyllograptus shales," in *Die silurischen Etagen 2 and 3*, etc. 1882. p. 18 ff). They found this Phyllograptus shale (3b) between the Ceratopyge limestone (3a γ) and the Megalaspis limestone (3c α).

Holm[2] obtained species of the Tetragraptus zone, such as T. bigsbyi and Phyllograptus angustifolius from glauconitic gray Orthoceras limestone (Planilimbata limestone) of Oeland and partly based on these his beautiful investigations regarding the morphology of these graptolites.

In *France* the following species, originally described from the Levis beds, Didymograptus pennatulus, D. nitidus, D. bifidus, D. indentus, Tetragraptus serra and T. quadribrachiatus, have been reported by Barrois[3] from the graptolite schists of Boutoury near Cabrières in the Languedoc. He correlates this schist with the middle Arenig (Skiddaw) of England, the Quebec beds of Canada and *étage* D d 1 β of Bohemia.

In the succeeding year the same distinguished author announced the discovery of the species described by Hall as Graptolithus richardsoni at La Mouchasse du

[1] Skanes Graptoliter I, in Sveriges Geologiska Undersökn. 1882. ser. C, no. 50.

[2] Sveriges Geologiska Undersökn. 1895. ser. C, no. 150.

[3] Annales de la Société Géologique du Nord. 1892. t. 20, p. 75 ff.

Temple (Cabrières), making it the type of the new genus Rouvilligraptus. As this species has to the writer's knowledge been found only in the St Anne beds, which are identical with the Deep kill zone (Did. bifidus zone) to be described next, it appears that both the Tetragraptus and the Didymograptus bifidus zones (St Anne beds) may be present at Cabrières.

From the auriferous shales of *Victoria, Australia*, Etheridge jr[1] has reported the occurrence of such well known Levis fossils as Tetragraptus bryonoides (=serra), T. quadribrachiatus, T. fruticosus, Phyllograptus typus, Loganograptus logani and Didymograptus nitidus, to which McCoy[2] has added Goniograptus thureaui. This list indicates the presence of the Tetragraptus zone in Australia.

The preceding brief review of a number of publications which announce the presence of the Tetragraptus fauna is sufficient to demonstrate the vastness of the area which it once occupied. Prof. Frech[3] has suggested the probability that there existed four grand marine provinces in the Lower Siluric which were more or less separated from each other, viz the Bohemian-Mediterranean, the Baltic, the North Atlantic and the Pacific-North American basins. The former existence and extension of these provinces is deduced from the comparative study of the horizontal distribution of the faunas, specially of their trilobite element. The graptolites however are expressly excepted as passing beyond the boundaries of these basins, and this phenomenon is explained by their pelagic or abysmal habitat in contrast to the littoral or shallowsea habitat of the provincial faunas. This necessity of contrasting the graptolite faunas with the other faunas on account of their vast geographic distribution, together with the well known fact of their short vertical range, is a conclusive demonstra-

[1] Ann. and mag. nat. hist. 1874. 4th ser. 1:41.

[2] Geol. surv. Victoria. Prodr. pal. Victoria. Decade 5, 1877. p. 39.

[3] Lethaea palaeozoica. 1897. 2:88 ff.

tion of their invaluable aid in exactly correlating parts of the Siluric system regionally widely separated. In the case of the Tetragraptus fauna, the precise determination of its position in the Beekmantown formation will permit a perfect correlation of that part of the Beekmantown formation with the highly subdivided Lower Siluric of northern Europe. Furthermore, as the graptolites changed so rapidly, and pelagic forms are not subject to the slow migrations of the littoral forms, but spread rapidly over wide territories, it is proper to conclude that this Tetragraptus fauna, like the succeeding faunas, conquered its territory in a very short time, and that we have here, hence, not only homotaxial, but actually synchronous beds of both hemispheres before us.

The fact mentioned above, that the English and Swedish faunas of this horizon have a greater number of species in common than they have with the Levis fauna, is, in this connection, worthy of special notice, as it proves that a world-wide and absolute identity of the pelagic graptolite faunas does not exist. This may indicate that there also existed geographic or regional differences, which, however, did not coincide with the differences in the distribution of the other fossil organisms, as has been suggested by Frech (*loc. cit.* p. 116) in view of the discrepancies observable in the succession of the two detailed series of upper Siluric graptolite zones, made out by Tullberg in Sweden and by Barrande in Bohemia.

Zone with Didymograptus bifidus and Phyllograptus anna

Graptolite bed 3

This bed has a thickness of 2 feet, and is separated by 14 feet of mostly barren limestone beds (bed h) from graptolite bed 2. It has furnished, partly in an excellent state of preservation, the following forms:

1	Dendrograptus *cf.* divergens *Hall*	r
2	Dictyonema *cf.* delicatulum *Dawson*	r
3	Callograptus salteri *Hall*	r
4	Dichograptus octobrachiatus *Hall*	r
5	Goniograptus thureaui *McCoy, var.*	c

6	G. *sp. nov.*	cc
7	Coenograptid *gen. nov. et sp. nov.*	c
8	Tetragraptus serra *Brong.* small mut.	c
9	T. bigsbyi *Hall* small mut.	c
10	T. fruticosus *Hall* small mut.	cc
11	T. pendens *Elles*	rr
12	Didymograptus *cf.* similis *Hall*	r
13	D. bifidus *Hall*	cc
14	Phyllograptus typus *Hall*	c
15	P. anna *Hall*	cc
16	P. angustifolius *Hall*	c
17	Nemagraptus *sp.*	r
18	Thamnograptus anna *Hall*	c
19	Lingula quebecensis *Billings*	rr
20	Small indet. brachiopods	cc

To this zone belong also the beds j, k, l, m and n, hard greenish silicious beds, sandy shales and limestones. Bed j bears, on black shaly partings, Didymograptus bifidus, the most characteristic form of this zone. The thin graptolite bed 4 in bed l also furnished this species and a few poorly preserved fragments of some of the other forms.

Graptolite bed 5

Under this notation have been united the numerous shaly partings between the heavy banks of greenish gray, extremely hard, silicious rock which is exposed, with a thickness of 52 feet, in the quarry at the east end of the continuous section (stratum o; the shaly partings are denoted on the diagram by the letter p). Most of these partings are covered to the exclusion of other species, with the rhabdosomes of the species Phyllograptus typus, Ph. ilicifolius (large mutation) and Ph. anna. The largest specimens of Phyllograptus typus occur however in a layer at the base of graptolite bed 3. The full list of the species observed in the quarry is:

1	Tetragraptus quadribrachiatus *Hall*	c
2	T. serra *Brong.*	r

3	Didymograptus bifidus *Hall*	cc
4	D. similis *Hall*	c
5	Phyllograptus typus *Hall*	ccc
6	Ph. ilicifolius *Hall*	cc
7	Ph. anna *Hall*	c

The faunules of the graptolite beds 3-5 receive their characteristic aspect from the new appearance and abundance of individuals of Phyllograptus typus, Ph. anna, Didymograptus bifidus, D. similis and Thamnograptus anna. The last four were, together with Tetragraptus fruticosus, described by Hall as occurring in the "Quebec group, 3 miles above the river St Anne." They pertain, hence, to an association not known to him from the Levis region, nor have they, to the writer's knowledge, been reported since from the Levis beds, with the exception of Didymograptus bifidus, which is listed by Ami (Geol. surv. Can. Rep't for 1887–88, 53 k) as found in an excavation near the City hall of Levis and by Gurley as occurring also in another Levis zone identical with the next succeeding Deep kill zone. Lapworth found Phyllograptus anna associated with some other species, which are common to this and the Tetragraptus zone, in the collections submitted to him from the south side of the St Lawrence river, and termed this the *St Anne zone or zone with Phyllograptus anna*. He correctly supposed it to belong to about the middle of the series of the Levis zones. Dr Gurley, in compiling the list of the North American graptolites, had no collection from the St Anne beds to refer to, and cites only the forms listed by Hall and Lapworth.

Though the fauna of this zone, as well in the shales of St Anne des Monts, as in the Deep kill beds, appears rather limited when compared with that of the preceding zone, it is notwithstanding of the greatest interest, first stratigraphically, as it clearly marks a distinct horizon or zone, which is also discernible in very distant regions, and secondly phylogenetically, as it indicates the approaching suppression of the

dichograptid graptolite stock. The latter fact finds its strongest expression in the remarkable restriction in the number of species of dichograptids, but is also recognizable in the character of the species remaining. Of the multiramous dichograptids only Goniograptus is left, which, as will be shown in another article, has here become so fixed and unchangeable in the number of its branches that it is clearly a final derivative of the freely branching older Clonograptus forms. The species of the genus Tetragraptus, which latter reached the acme of its development in the preceding zone, are, with the exception of T. quadribrachiatus, crucifer and alatus, still present, but are represented only by smaller mutations. The genus Didymograptus, which lived into the Trenton period, and with a few species of its subgenus Leptograptus even extends into the Utica period, appears with two new species, which are restricted to this zone, and one of which, Didymograptus bifidus, is in the Deep kill section the most characteristic species of the zone, as it is extremely common in the beds, extends neither above nor below the zone and is the first of the "tuning fork" species of the genus, which in Europe are quite characteristic of still higher zones. The genus Phyllograptus attains in this zone in Ph. typus its greatest size and variability within the boundary of a species but is also represented by the diminutive Ph. anna, which also extends into the next zone and foreshadows or closes the life history of this peculiar genus. Finally there appears in this zone the first of the coenograptids, which attain their full development not before the middle part of the Champlainic or Lower Siluric.

Lapworth[1] reports a similar association, characterized by Didymograptus bifidus, D. extensus, Phyllograptus typus, Tetragraptus bryonoides and T. quadribrachiatus from the "Ballantrae rocks" in Ayrshire, south Scotland. Miss Elles lists Didymograptus bifidus as occurring in the middle and upper Skiddaw

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[1] Geol. mag. 1889. 3d ser. 6:22.

slates. In the latter (Ellergill beds) it is, however, reported to be associated with forms which are characteristic of the next higher Deep kill zone, while the species, associated here with D. bifidus, specially Phyllograptus typus and P. anna, are according to Miss Elles found there in the middle Skiddaw slates. In regard to this association it is stated (*loc. cit.* p. 529): "Tetragraptus serra (Brong.) and other forms are also found associated with the fauna which in Sweden characterizes the zone of Phyllograptus *cf.* typus and occur on the same slab as the earliest tuning fork Didymograpti." This association forms the *upper Tetragraptus subzone* (corresponding to the upper Arenig) *with which we have to correlate the present Deep kill zone or the St Anne beds of Canada.*

In *Scania* the zone with Phyllograptus *cf.* typus and Didymograptus *cf.* bifidus forms, according to Tullberg, the highest part of the lower Graptolite shale and overlies the Orthoceras limestone (limestone with Megalaspis planilimbata and Megalaspis limbata). But, as this zone is also reported to contain Climacograptus and Cryptograptus, which here do not appear till the next zone, this Scanian and the Deep kill zone can not be exactly parallelized; and it is to be assumed that the former holds a position intermediate between this and the next Deep kill zone, and that the *St Anne beds are homotaxial with the Megalaspis limestone itself.*

In *Bohemia* a form from *étage* D d 1 γ has been identified with Didymograptus bifidus by Dr Perner;[1] and in France, as noted before, Didymograptus bifidus and Rouvilligraptus richardsoni, two species of the St Anne beds, have been reported from the graptolite shales of Cabrières. Finally, the zone with Didymograptus bifidus was recognized by T. S. Hall[2] as a separate horizon in the auriferous shales of Victoria in Australia, where it also overlies the Tetragraptus zone. It appears that in Australia and New

[1] Etudes sur les Graptolites de Bohême. 2ième partie. 1895. p. 23.

[2] Austr. ass'n adv. sci. 1893. 5: 374.

Zealand the entire Lower Siluric is represented by graptolite shales with forms of world wide distribution.

Zone with Diplograptus dentatus and Cryptograptus antennarius

In the exposure produced by the construction of the dam of the Lansingburg waterworks two graptolite beds were noticed:

Graptolite bed 6

This bed contained, embedded in a massive dark mud rock:

1	Phyllograptus angustifolius *Hall*	c
2	Ph. *sp. nov.*	c
3	Diplograptus dentatus *Brong.*	r
4	Retiograptus tentaculatus *Hall*	c
5	*Cf.* Trigonograptus ensiformis *Hall* (fragments)	r

A larger fauna was obtained from

Graptolite bed 7

This bed consists of soft, black shale, the bedding planes of which are profusely covered with specimens. It furnished the following fauna.

1	Dendrograptus *sp. nov.*	c
2	Dictyonema *sp. nov.*	cc
3	D. *sp. nov.*	c
4	D. (Desmograptus) cancellatum *Hopk.*	c
5	D. (D.) *sp. nov.*	c
6	Callograptus diffusus *Hall*	r
7	C. *sp. nov.*	r
8	Ptilograptus plumosus *Hall*	rr
9	Loganograptus logani *Hall*	rr
10	Dichograptus octobrachiatus *Hall* (hexad type)	c
11	Didymograptus (Isograptus) gibberulus *Nich. var.* nanus, *var. nov.*	c
12	D. *sp. nov.*	rr
13	Leptograptus *sp. nov.*	r
14	Nemagraptus *sp. indet.*	c
15	Diplograptus dentatus *Brong.* (=D. pristiniformis *Hall*)	ccc
16	D. inutilis *Hall*	r

17	D. *sp. nov.*	
18	Retiograptus tentaculatus *Hall*	r
19	Glossograptus *sp. nov.*	c
20	Cryptograptus antennarius *Hall*	ccc
21	Trigonograptus ensiformis *Hall*	cc
22	Climacograptus *sp. nov.*	c
23	Lingula quebecensis *Billings*	r
24	Eunoa accola *Clarke*	r

Continuous with this bed of black shale is a layer of purplish gray shale with numerous light blue specks, probably originating from talcose mud pebbles. This layer contained:

1	Dichograptus *sp.* (branches)	c
2	Phyllograptus anna *Hall*	c
3	Diplograptus dentatus *Hall*	cc
4	D. *sp. nov.*	r

The aspect of the faunas of these two graptolite beds, which clearly belong to one zone, is totally different from that of the two preceding zones. Not only are all species new, with the exception of Loganograptus logani, Dichograptus octobrachiatus, Phyllograptus angustifolius, Ph. anna and Lingula quebecensis, and the prevailing genera different, but even the subclass of the Axonolipa, which hitherto alone held the field, has almost entirely been replaced by the family Diplograptidae of the Axonophora. The latter are represented by the genera Diplograptus, Climacograptus, Glossograptus, Cryptograptus, Trigonograptus, and Retiograptus.

A peculiar feature of this fauna is the sudden outburst of the Dendroidea with a Dendrograptus, four species, in numerous individuals, of Dictyonema (two of these of the rare subgenus Desmograptus), two Callograptus and a Ptilograptus. This subclass however, though reaching its acme already in Cambric beds, reappears, as is well known, with great force in the Niagaran and extends even into the Hamilton formation. As only the species of Callograptus and of Ptilograptus, one of each genus, are recorded from the Canadian exposure of this zone, the greater number of species and the profusion of speci-

mens of this long lived subclass may be of a merely local character.

On account of the radical changes in the composition of the fauna and of the large break in the section between the preceding and this zone, which, taking the average dip of the beds into account, may represent 300 feet of covered rock, it might be surmised that a number of zones must be missing between the two, and the succession of the zones is incomplete in this regard. Reference to the European succession of zones shows however that this is hardly the case, for in the Skiddaw beds, for instance, the same two zones have been found in direct succession. It is true, there may exist an intermediate, transitional zone, containing a more balanced mixture of the two faunas, such as has been found in Scania (*see* above, p. 569).

All the species of this fauna, described by Hall, were cited by him simply as coming from the Quebec group of Point Levis. In each description, however, the association is recorded in which the form was found, and from these records it becomes evident that the separate existence of this peculiar assemblage of species at Point Levis was well known to that illustrious observer. Lapworth (*loc. cit.*) found no material from this zone in the collections submitted to him, and therefore does not mention or locate this horizon in his series of graptolite zones.

Dr Gurley (*loc. cit.* p. 302) states that besides the fauna of the Main Point Levis zone he had before him a smaller collection of Point Levis shales, from a locality 1½ miles north of the east railway station at Levis, which has a strikingly different fauna; adding: "It was remarkable not so much for the species present (though the Diplograpsidae seem highly characteristic) as for those absent." His Ordovician table of graptolites (*loc. cit.*, p. 296 ff) proves that the third Deep kill fauna is identical with this second Point Levis fauna. Gurley calls the latter simply the "*Point Levis fauna*," and, together with two similar associations, from the Piñon range at Summit Nev., and from Arkansas, refers it to the upper Calciferous zones.

In *England* the zone with Diplograptus dentatus, Cryptograptus antennarius and Trigonograptus ensiformis is well developed in the *Ellergill*

beds, which form the lower part of the upper Skiddaw slates. Didymograptus bifidus rises there into this zone, while, on the other hand, Phyllograptus anna and Phyllograptus angustifolius are not reported by Miss Elles from these beds. Marr,[1] however, also cites the latter species. As Dr Gurley has also found Did. bifidus in the corresponding Point Levis zone and Phyllograptus anna in association with these Diplograptidae in Arkansas, it is apparent that these species rise in various regions into this zone.

The Ellergill beds are correlated by Lapworth, Marr and Elles with the *Llanvirn beds of Wales;* and by Miss Elles with *Tullberg's zones n), zone of Glossograptus* and *o), zone of Didymograptus geminus*, which form the basal part of the middle graptolite shales or of the *Dicellograptusskiffer* of Scania. These zones also contain the genera Diplograptus, Climacograptus, Glossograptus and Cryptograptus. The latter zone has again been subdivided into three subzones, the lowest of which (γ) still contains Didymograptus bifidus. This would suggest that the presence of the above cited species of the Phyllograptus anna zone in the zone with Diplograptus dentatus in America may eventually allow the recognition of subzones in the latter.

It will be noticed that in England this zone is placed above the Arenig formation, and that the corresponding zone in Scania is united with the middle graptolite shales, that, hence, important formational boundaries separate, in Europe, this and the preceding zone. This fact, in connection with the decided change in the character of the genera, which are those of the Middle and Upper Champlainic or Lower Siluric, may with our advancing knowledge of the graptolite facies of the Champlainic lead to the correlation of this zone with some part of the Chazy formation. This supposition seems to be well supported by a statement of Mr Walcott (*see* Gurley, *loc. cit.* p. 304), that "in Nevada Didymograptus bifidus occurs in strata certainly supra-Calciferous and probably of Chazy horizon."

[1] Geol. mag. 1894. 14th ser. 1:127.

SUMMARY

The Deep kill section has furnished extensive collections of three different graptolite horizons which, termed after their most characteristic organisms, are:

c Zone with Diplograptus dentatus and Cryptograptus antennarius

b Zone with Didymograptus bifidus and Phyllograptus anna

a Zone with Tetragraptus

Two of these zones (*a* and *b*) are found in contiguous succession, the third is separated by a break in the exposure, but is certainly superjacent on the second zone *b*. In Great Britain and Scandinavia, all three zones have been observed in the same succession. In Canada, zone *a* is known from several regions, the most important being the Levis and St John regions. The typical fauna of zone *b* has become known from the beds near the St Anne river in Canada, and zone *c* is again present in the Levis beds. The succession of these zones has thus far not been reported as observable in any of these Canadian regions.

The stratigraphy of the Deep kill section demonstrates that the Main Point Levis beds or those of the Tetragraptus zone are the lowest of the series; that they are followed by the St Anne beds or those of the zone with Didymograptus bifidus etc., and *that the Point Levis beds, containing the zone with Diplograptus dentatus etc., overlie either directly the St Anne zone or are separated from it by only an intermediate transitional zone.*

As the Levis beds have been demonstrated to belong to the Beekmantown or Calciferous formation, the two lower of the zones certainly represent part of the graptolite facies of that formation, while the third zone may either belong to this or to the Chazy formation.

In using the results of a former investigation by the writer of the shales in the vicinity of Albany (N. Y. state mus. Bul. 42) the zones recorded in the first column of the following correlation table of the Champlainic or Lower Siluric graptolite shales can be claimed to have been discerned in this region.

Correlation table of the zones in the Champlainic (Lower Siluric) of the vicinity of Albany

Formation	Vicinity of Albany	Canada		Great Britain		Scandinavia (Tullberg)	Other regions
Lorraine	Zone with Dipl. foliaceus Coryn. curtus and Lorraine fossils (Waterford)	Lorraine beds	Caradoc	Zone with Dicellogr. anceps (Upper Hartfell shales) upper Caradoc of Shropshire with Dipl. foliaceus etc.	Middle Graptolite schists	Zone with Dipl. *sp. nov.*	Upper Maquoketa shales (Ohio and Miss. valley)
Utica	Zone with Dipl. quadrimucronatus, D. foliaceus, D. pusillus, Coryn. curtus, Triarthrus becki etc. (Rural cemetery etc.)	Utica beds with Dipl. quadrimucronatus (Quebec, etc.) and Leptogr. flaccidus (Lake St John)		Zone with Dicellogr. complanatus (Upper Hartfell)		Zone with Dicellogr. complanatus	Dd 5 of Bohemia with Dipl. pristis
	Transitional zone with Climacogr. caudatus, Cryptogr. tricornis, Triarthrus becki etc. (Mechanicsville, Van Schaick island)			Zone with Pleurograptus linearis, D. quadrimucronatus, etc. (Lower Hartfell)		Zone with Dipl. quadrimucronatus	Lower Cincinnati, lower Maquoketa shales (Ohio valley)
Trenton	? Upper Dicellograptus zone (Lansingburg powerhouse)	Upper Dicell. zone (Quebec and Magog, Gurley) (= zone without Coenogr. gracilis Lapw.)		Zone with Dicranogr. clingani (Lower Hartfell)		Zones with Climacograptus vasae, Dicranogr. clingani etc.	Shale of Gembloux (Ardennes) with Climac. caudatus, Cl. styloideus, and sandstone of St Germain-sur-Ile with Dipl. foliaceus and D. angustifolius
	Zone with Dipl. amplexicaulis (Troy)			Zone with Climaco. wilsoni (Lower Hartfell shales, Moffat etc.)			
	Lower Dicellogr. zone (Normanskill beds)	Lower Dicellogr. zone (Quebec, etc. Gurley) (= zone with Coenogr. gracilis Lapworth)	Llandeilo	Zone with Coenogr. gracilis (Lapworth) Lowest Moffat beds, Glenkiln shales		Zone with Coenogr. gracilis	Shale with Coenogr. gracilis of Victoria, Australia. Shales of Arkansas
Chazy	?	Beds of Mystic (Gurley)					? Graptolite shales of Kicking Horse pass, and Dease river, British Columbia (Gurley) ? shales of Nevada
Beekmantown	Zone with Dipl. dentatus and Cryptogr. antennarius (Deep kill)	Point Levis zone (Gurley)		Ellergill beds (Elles) (= Llanvirn, Elles)		Zones with Glossograptus and Didymogr. geminus	Grapolite shales of Arkansas and Nevada
	Zone with Didymogr. bifidus and Phyllogr. anna (Deep kill)	St Anne zone (Lapworth and Gurley)	Arenig	Upper Tetragraptus zone (Skiddaw slates, Elles) Upper Arenig beds of Scotland and Wales	Lower Graptolite schists	Zone with Phyllogr. typus and Didymogr. bifidus	Shales of Cabrières, France. Dd 1 of Bohemia with Didymogr. bifidus, Auriferous shales of Victoria, Australia
	Zone with Tetragraptus (Deep kill)	Main Point Levis zone (Gurley)		Lower Tetragr. and Dichogr. zones (Skiddaw slates, Elles). Middle Arenig graptolite beds of Scotland and Wales		Tetragraptus shales	Shales of Huy-Statte and Sart-Bernard (Ardennes) with Phyllogr. Dichogr. and Tetragr. Auriferous shales of Victoria, Australia

MODE OF GROWTH AND DEVELOPMENT OF GONIOGRAPTUS THUREAUI *McCoy*

BY RUDOLF RUEDEMANN

In 1889[1] Dr Ami announced the occurrence of Goniograptus thureaui in the Tetragraptus zone of Levis, Quebec. This remarkably pretty graptolite, the generic type and only species of the genus Goniograptus, was till then known only from the graptolite beds of the Bendigo gold field, Sandhurst, Victoria, Australia, whence it was described by McCoy.[2] It is there, as in the Levis and Deep kill beds, found associated with the species characteristic of the Tetragraptus zone. Dr Ami figured a remarkably large and perfect specimen and added the description of the central disk which extends in a peculiarly alate manner along the branches.

In the Deep kill section numerous hydrosomes of this species have been found, not only in the Tetragraptus zone, but also in the beds of the overlying zone with Didymograptus bifidus and Phyllograptus anna. The material from the former zone proved to be of special interest for the study of the ontogeny of the species, for it contained a complete series of finely preserved growth stages from the sicula onward to the mature colony. These stages allow the elucidation of some points in the ontogeny and morphology of the multiramose dichograptids which were hitherto not well understood; and they have therefore been made the subject of this notice.

A restricted number of characteristic stages has been figured. The outlines of the figures have, with one exception, been drawn with the camera lucida and reduced to their present size.

Sicula. The sicula itself is rather short and stout, as those of many other dichograptids; it can, therefore, when alone, be hardly distinguished from the siculae of several other species occurring in the same beds.

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[1] Can. rec. sci. 1888–89. 3:422, 502.

[2] Ann. and mag. nat. hist. 1876. p. 128; Geol. Sur. Victoria. Prodr. pal. Victoria. Decade 5. 1877. p. 39.

Thecae. From this sicula buds at first, close to its distal end, one theca (1), which for a short distance grows in a distal direction along the sicula, then, turning abruptly under an approximately right angle, follows a horizontal or slightly downward direction (assuming the suspended position of the colony). (*See* fig. 1 and 3) The apparent angle of its divergence changes slightly, as is illustrated by fig. 2 and 3. From theca 1 is produced again by gemmation and close to its proximal end theca

Fig. 1 Goniograptus thureaui McCoy. var. postremus. Sicula and first two thecae (funicle). x3½

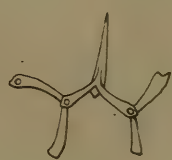

Fig. 2 *Idem.* Sicula (from antisicular side); and branches of first and second order. x3½

Fig. 3 *Idem.* Same, from sicular side. x3½

2, which, growing across the "antisicular" side of the sicula, diverges to the opposite side under exactly the same angle as theca 1. In older colonies the thick, straight, uninterrupted cross bar between the principal branches has been termed, in other multiramose dichograptids, the "funicle" by Hall and succeeding authors on graptolites. As the somewhat larger colonies usually settle on their broader surfaces, the sicula is brought into a vertical position, and hence often fails of observation in the fossilized state, as in fig. 4, where the central thickening indicates its location.

Each of these primary thecae produces in its turn (fig. 3), in a like position and manner as the sicula did, a new theca, which also, after a short adherence to the mother theca, turns aside at the same angle as does theca 1 and, like the latter, sends a new theca, corresponding to theca 2, to the opposite side. The bifurcation near the aperture of the sicula of the first two thecae is hence repeated at the aperture of each of the latter, and four secondary thecae result. These four thecae form the four "primary branches" of other authors. Each of these produces a new bifurcation (fig. 5 and 6) by the same process of twice repeated gemmation in two succeeding thecae, and the

assumption of opposite directions of the new branches. This would furnish eight "secondary branches". But a material change now takes place in the arrangement of the new thecae,

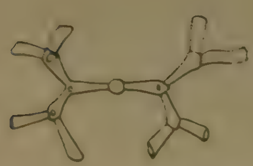

Fig. 4 *Idem.* Branches of third order have begun to form. Vertical view. x4

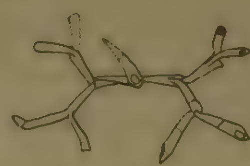

Fig. 5 *Idem.* Same growth stage. Sicular view. Shows mode of branching on left side. x3½

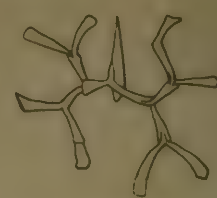

Fig. 6 *Idem.* A little more advanced stage. Antisicular view of sicula. x4

growing from these eight tertiary thecae. If we give the funicle a horizontal position in the drawing (fig. 7, 8), the four thecae (*a*) of these eight tertiary ones, which lie on the side of the vertical axis (A–B in fig. 8), produce thecae which do not diverge from their mother thecae, but retain the direction of the latter. This leads to a serial arrangement of the thecae and to the "denticulate branches" of other authors. The other four tertiary thecae (*b*) however, which lie subparallel to the funicle, produce a new

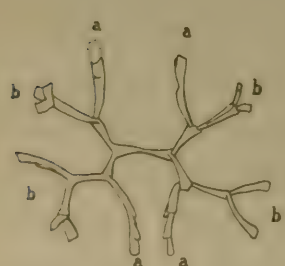

Fig. 7 *Idem.* Next growth stage. Differentiation of arrangement of thecae has commenced. *a* branches with serially arranged thecae; at *b* dichotomy continuing. x2½

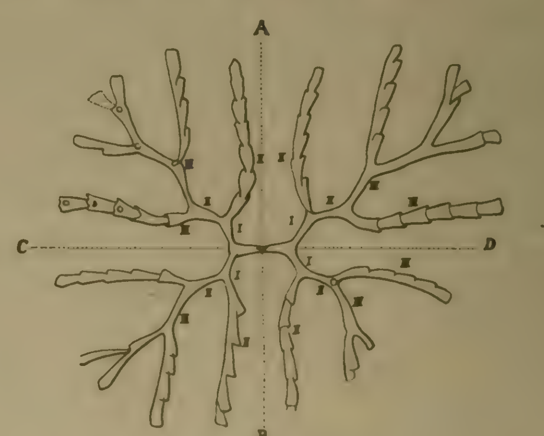

Fig. 8 *Idem.* A further advanced growth stage, which shows more distinctly the differentiation of the tertiary branches (III) and the composition of the four principal stems of thecae (see thecal apertures in upper left quarter). x2½.

bifurcation. They become thus component parts of the principal stems of the mature colonies.

Of the eight tertiary branches (marked III in fig. 8) resulting from these bifurcations, those subparallel to the funicle become denticulate, while the others bifurcate again.

This process of dichotomous branching and of the development of one of the resulting branches into a denticulate branch is repeated with absolute regularity. The result is the formation of four zigzag-shaped principal stems, lying in the diagonals of the rectangle, and of two alternating series of denticulate branches on each of these stems.

Fig. 10, 11 are reproductions of more advanced stages which differ from the younger ones principally in the length attained by the denticulate branches. Both specimens bear 24 such

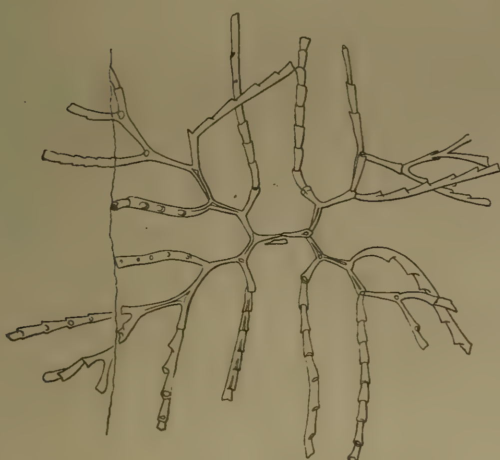

Fig. 9 *Idem*. Hydrosome with complete number of branches seen from thecal side. x2⅓

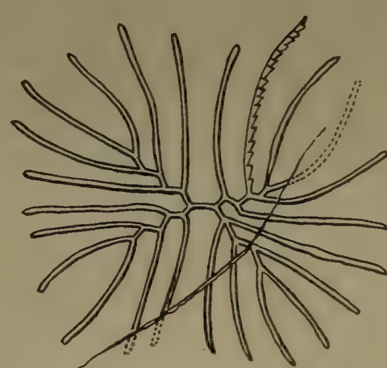

Fig. 10 *Idem*. Stage where dichotomous branching has ceased and all new thecae arrange themselves serially. Nat. size

branches, six on each stem and none of the many hydrosomes obtained at the Deep kill have a greater number of branches than six. As the ultimate branches of the stems are both denticulate, dichotomous branching appears to have ceased, and 24 seems to be the maximum number produced by these colonies. Dr Ami, however, figures a very large specimen, which, when complete, would have had about 80 branches. Specimens in the writer's hands attain about three fourths of the size of that referred to, without bearing more than 24 branches; also the smaller specimen figured by Dr Ami possesses a greater number of branches than colonies of like size in the Deep kill collection. These facts seem to indicate that the latter material contains a variety which, in the process of reduction of the number of branches, observable throughout the Dichograptidae, has advanced a decided step beyond the original Goniograptus thureaui,

and, like Dichograptus octobrachiatus and Tetragraptus, reached a stage with a fixed and more limited number of branches. This form would then stand at the

Fig. 11 *Idem.* Mature hydrosome. Shows the restricted number of branches (24), in this variety. Nat. size

end of the Goniograptidae, as far as the genus is known, and might be designated as Goniograptus thureaui var. postremus.

The important ontogenetic and morphogenic facts of which this series of growth stages permits a statement are:

1 *The "funicle" of Goniograptus consists of two thecae.* The equal length of the two parts of the funicle between the sicula and the first dichotomy and of the primary branches in the other multiramose dichograptids indicates that the funicle is in all these constructed of two thecae. With advancing growth of the colony, the two thecae of the funicle, like those of the principal stems, become greatly thickened and assume the form of cylindric stems, thus more or less losing indications of their former thecal nature (fig. 10 and 11). The statement, found from Hall's work onward in nearly all descriptions of the colonies of these multiramose dichograp-

tids, that the funicle is destitute of cellules, is, hence, correct only in so far as the denticulations or the apertural parts of the thecae are only distinct in young specimens and noticeable only at the points of bifurcation, but not along the funicle itself.

As to the group of Dichograptidae, represented by the genera Temnograptus, Schizograptus, Ctenograptus, Holograptus, Rouvilligraptus and Trochograptus Holm has noted the presence of a theca on each side of the sicula in the funicle of Trochograptus diffusus. Concerning the structure of the funicle in general that keen observer states:[1]

On these grounds, and in consideration of the many-branched Dichograptidae being embedded in shale, and therefore showing the thecae of the central part of the polypary only in very exceptional favorable cases, and as these thecae are analogous to those in Didymograptus and other forms which are better exposed, I draw the conclusion that the funicle in many cases, if not always, was furnished with thecae.

This conclusion is fully verified as to Goniograptus and Coenograptus (fig. 13) by the writer's material. It becomes apparent from these observations that the funicle does not differ in structure from any other part of the stem; and probably in all Dichograptidae consisted of two thecae.

2 *The four principal stems of Goniograptus are composed of thecae, each internode between two bifurcations consisting of one theca.* For this reason all these internodes are of uniform length, and, because the angle of divergence of the budding thecae is constant throughout, the angles of bifurcation are all alike.

The next related genus, Clonograptus, which develops the greatest number of branches and is most irregular in the extent of its branching, has been considered, on account of these characters and its earlier appearance, the progenitor of a part of the multiramose dichograptids. It is a well known character of this genus that the internodes between the bifurcations not only grow to extreme length, but also

[1] Geol. mag. 1895. 4th ser. 2:484.

increase in length toward the distal parts of the hydrosome. That these very long stem-internodes, e. g. Cl. flexilis and Cl. rigidus, actually always consist of but one theca, as the increasing length of the stem thecae in fig. 12

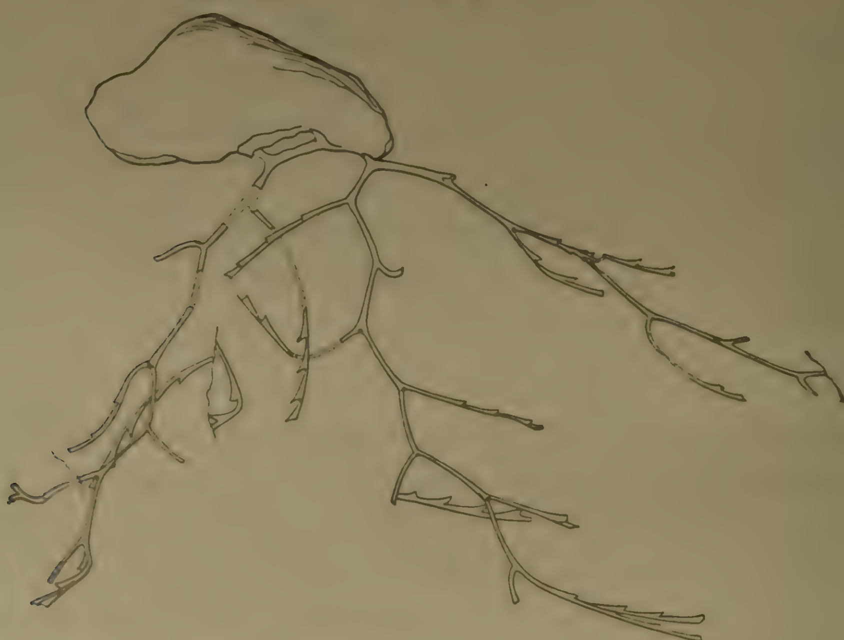

Fig. 12 Clonograptus (Goniograptus) *sp. nov.* Possesses long stem internodes, each consisting of but one theca. x2⅓

would suggest, the writer is not prepared to assert. As the stems of these forms, in conformity with Hall's fundamental views, have been currently considered as entirely indenticulate or free from thecae, they have not been investigated as to their structure, and conclusive data on the number of thecae in each internode are not to be obtained in the literature. Hall's position[1] was this:

Neither the central portion, nor any of its subdivisions, becomes celluliferous; and these parts are not termed stipes or branches, according to the views I have entertained. It is only beyond the last subdivisions of this part of the body, as in G. logani, that the celluliferous parts, or the true stipes, commence.

Miss Elles[2] states that she has observed thecae on stipes of every order in Clonograptus flexilis. Of special interest in this connection appear to be the description and illus-

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[1] Can. org. rem. Decade 2. 1865. p. 20.

[2] Quar. jour. geol. soc. 1898. 54: 473.

tration of a Cambric species published by G. F. Matthew.[1] In this form the primary branches are short and evidently composed of one theca only, while all the branches of a higher order are longer and distinctly figured as consisting of several thecae.

If we compare this species with the lower Siluric species of Clonograptus or with the species of Dichograptus and Loganograptus, *e. g.* L. logani, where the primary and secondary branches are equally short, a tendency toward a concentration of the dichotomous branching in the central part of the colony becomes apparent.

The genotype of Dichograptus, D. octobrachiatus, and that of Loganograptus, L. logani, are found associated with Goniograptus in the Deep kill section, and occur in younger specimens, which indicate that these genera also conform to the composition of the internodes of one theca each.

The denticulate nature of the branches of the first and following order in Temnograptus was already known to Hall (Gr. milesi Hall) and has been recognized in its related genera (Holograptus, etc.).

Holm has described a coenograptid (Pterograptus elegans),[2] with a distinct thecal structure in the two principal stems, and the writer figures (fig. 13) a young specimen of Coenograptus gracilis itself, which distinctly shows the thecal structure of these stems.

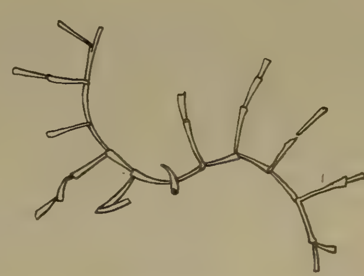

Fig. 13 Coenograptus gracilis Hall. Young hydrosome, which shows composition of funicle and principal stems of thecae. Normanskill shale of Mt Moreno. x4

It becomes therefore probable that all parts of the hydrosome of the Dichograptidae, including funicle and principal stems, consist of thecae; with the exception of the nema, which carries the sicula, and of the central disk.

3 *The growth stages of Goniograptus indicate that the bifurcations of the branches throughout the hydrosome take place in*

[1] N. Y. acad. sci. Trans. 1895. p. 295.

[2] Öfversigt af K. Vet. Ak. Förhandl. 1881. no. 4, p. 77.

the same manner as the formation of the funicle by the sicula, viz by the successive budding of two thecae, the second of which buds from the first, and both of which, assuming diverging directions, determine the direction of the ranches. This shows that the sicula, with its distal part, holds the position of a first theca, and that the funicle is genetically and morphologically not different from the branches of a higher order. From growth stages of Dichograptus and Loganograptus, obtained in the Deep kill collection, it can be deduced that the dichotomous branching of these genera conforms to the same law. The hydrosome of a new species of Bryograptus, common in the Tetragraptus beds, possesses the same mode of branching.

Holm[1] has demonstrated that in Didymograptus, Tetragraptus and Phyllograptus the same mode of branching persists.

As to the nature of the branching which has been termed "monopodial" or "lateral," and which is characterized by the continued growth of the original branch in the same direction after division, I have been unable as yet to obtain any conclusive facts. The genera which show this mode of branching most typically, are Schizograptus, Trochograptus, Holograptus and Rouvilligraptus. The fact, however, that both dichotomous and monopodial branching coexist in the hydrosomes of these genera, seems to indicate, that there can be no fundamental difference between them. Observations on Coenograptus (fig. 13) indicate the correctness of the suggestion of Wiman[2] that this mode of branching is produced by the greater strength which is attained by the mother theca before it produces the daughter theca, and which enables the former to retain its original direction while it compels the latter to a change of direction.

4 There must have existed physiologic and morphologic differences between the zooids of the biserially arranged

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[1] Sveriges Geologiska Undersökn. Afhandl. och uppsatser. 1895. ser. C. no. 150.

[2] Geol. Inst. Upsala. Bul. 1895. no. 4, v. 2, pt 2, p. 34.

thecae of the branches and those of the dichotomously dividing stems of Goniograptus which find their expression in the thecae. It may *a priori* be assumed that innate differences caused the zooids of the stems to assume widely diverging directions and those of the branches to grow in the direction of the mother theca. It is further evident that the essentially or solely nutritive zooids of the branches or stipes persisted in performing the function of nutrition while those of the stems (funicle, etc.) served this function only in the early stages of the colony, and later on, when they became thickened by chitinous deposits into cylindric stems (compare fig. 10, 11 and Hall's figures of Clonograptus rigidus), assumed as their principal or sole function the supporting of the branches. It is partly on account of this secondary adaptation to the latter function that the thecal nature of the stems has failed, till lately, to be recognized in the majority of the dichograptids.

This difference in function is, to some extent, also expressed in the morphologic differences between the stem thecae which we here call stolonal thecae,[1] and the branch thecae which may be termed brachial thecae. If one compares the extreme thecae of the branches of Goniograptus with those forming the stems (fig. 10, 14), one can not fail to notice that they differ. The latter, stolonal thecae, are more cylindric, very slightly widening toward the aperture and without any submucronate apertural processes; they, therefore, usually fail to appear as "denticulations." Their apertures are small, circular openings (fig. 3, 4, 5). The fully developed distant thecae in the branches widen more abruptly toward the aperture, have wider apertures and submucronate processes on the outer apertural margins. These differences can not be due to different degrees of compression in consequence of different thickness of periderm, or be caused solely by the superposition of the thecae on the branches.

[1]The first theca of each "denticulate" branch is to be considered as a stolonal theca on account of its assuming a direction different from that of the mother theca.

It must however be conceded that, as the initial thecae of the branches (fig. 14) are similar to the stolonal thecae, a phylogenetic element, to be discussed later, enters into this problem. But, even if to this latter element the principal weight in explaining the morphologic differences is given, the difference of direction assumed by the stolonal and brachial thecae, and the later thickening and functional change of the former, are sufficient to indicate an important difference in the zooids that once occupied the thecae.

5 *The stolonal thecae are more similar in shape and relative size to the sicula of the colony than the brachial thecae.* They widen in a similar degree and possess the same simple apertural margin.

In general, it may be said that all the thecae of a hydrosome conform to some extent to the sicula of that hydrosome, forms with long, slender sicula, having similar thecae and such with wider, shorter sicula, as numerous Tetragrapti and Didymograpti, having correspondingly shorter thecae; but at the same time, the sicula of each colony is still relatively longer and narrower than the average or extreme brachial theca.

A comparison of the form of the thecae of the younger dichograptid genera, as of Dichograptus, Tetragraptus and Didymograptus, with that of the older and presumably also phylogenetically preceding genera, Bryograptus and Clonograptus, shows that, in general, the older genera have the more tubular, simpler thecae with less protracted apertural margins. It is, hence, apparent that the stolonal thecae and the sicula represent the older type of thecal form.

6 The growth stages of the hydrosomes of Goniograptus thureaui prove further that also *within each branch only siculoid thecae are at first produced* (fig. 9, 10, 14). In fig. 14 the basal and distal parts of a branch of Goniograptus have been still further enlarged to show their differences more distinctly. The earlier thecae *a*, are tubular, lie subparallel to the axis of the branch (the angle between the axis and their outer margin is only 7°), overlap not more than one fourth of their length, have a straight aperture without marginal process,

while the later thecae *b*, widen more rapidly, lie more divergent from the axis of the branch (their outer margin forms an angle of 28° with the axis), overlap more than one half, have concave apertures and a slightly projecting outer apertural margin.

7 It becomes apparent from these observations that the thecae of the colony of Goniograptus, from the sicula through the stolonal and early brachial thecae to the distal brachial thecae, form an ontogenetic series, which furnishes a clear and interesting example of "localized stages of development", the existence of which has been demonstrated and their character elucidated by R. T. Jackson.[1] In this remarkable publication it is stated (p. 90):

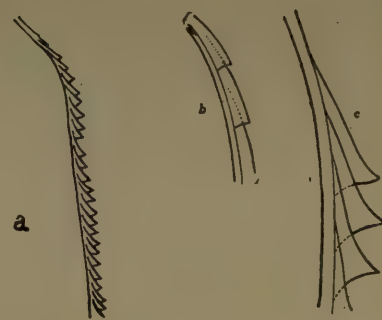

Fig. 14 Goniograptus thureaui var. postremus. *a* branch; *b* proximal thecae enlarged; *c* distal thecae enlarged.

> In organisms that grow by a serial repetition of parts, it is found that there is often an ontogenesis of such parts, which is more or less clearly parallel to the ontogenesis of the organism as a whole. In the ontogeny of such localized parts in a mature individual, we find stages in the development during the growth of the said part which repeat the characters seen in a similar part in the young individual. To state it briefly for the moment, such localized stages have been observed in the leaves of plants, in branches or suckers of plants, in the budding of some lower animals, as Hydra and Galaxea, in the plates of crinoids and Echini, in external ornamentation in mollusks, and in the septa of cephalopods.

From the examples cited those of Hydra and Galaxea are the most pertinent to our inquiry. In regard to them Prof. Jackson makes the following note (p. 141):

> In animals which produce asexually by budding, as Hydrozoa and Actinozoa, it seems that the bud may be considered a localized stage. The bud has not the stages seen in early embryonic development from the egg, but repeats in general the later stages seen in such ontogeny. A bud is not a new individual in the full sense of the word, but is an outgrowth from an older individual by a special localized development.

[1] Bost. soc. nat. hist. Mem. 1899. v. 5, no. 4.

Fig. 15 Tetragraptus fruticosus Hall. Branch which shows progressive change of thecae. x2½

The application of the results of Jackson's investigations to the colony of Goniograptus is fruitful in more than one regard. It permits us to conclude that the branches of the hydrosome, like the leaves of a tree, indicate individually by their ontogeny the path along which they have been developed. The ontogeny of the branches demonstrates that the phylogenetically preceding forms possessed branches composed of more tubular thecae, with less overlap, looser arrangement, smaller deviation from the direction of the axis of the branch and straight, not mucronate apertures. Likewise, the whole colony was derived from colonies composed of such thecae, which are still retained in its oldest parts. The Cambric species of Bryograptus and Clonograptus exhibit well these types of thecal arrangement and structure. In the genera Tetragraptus, Didymograptus and Phyllograptus, where, within the Dichograptidae, the thecae have advanced farthest beyond their original form, the process of ontogenetic acceleration has also gone farthest in effacing all vestiges of the original thecal form, as *e. g.* in Didymograptus (Isograptus) gibberulus, where no sicoidal thecae are preserved. In others, however, as a study of Hall's excellent figures of the various species of Didymograptus will show, the gradual change from tubular to more gibbous, more closely arranged and more erect thecae can clearly be traced. The writer desires to illustrate these ontogenetic changes in the stages and arrangement of

the thecae within the branches by figuring a remarkably large and well developed specimen of Tetragraptus fruticosus (fig. 15) and a smaller new species of Tetragraptus, which eventually will be described as T. taraxacum (fig. 16). The latter species is characterized by remarkably slender proximal thecae and an abrupt change to erect, broad distal thecae.

Fig. 16 Tetragraptus taraxacum *sp. nov.* **Shows abrupt change from narrow to wide thecae. x3½**

Fig. 17 Didymograptus (Leptograptus) *sp. nov.* **Possesses short proximal and long distal thecae. x3½**

That the direct opposite pattern to this compact structure represented by Tetragraptus and Isograptus, namely the extremely slender and graceful colonies of Leptograptus with their long filiform thecae, are likewise derived from a form having the Bryograptus type of thecal structure, is shown by the colony of a new species of Leptograptus from the Deep kill beds, which is represented in fig. 17. Here we have in contrast to the ontogenetic changes noted before, tubular proximal thecae, succeeded, as the branches lengthen, by extremely thin and long distal thecae which hardly deviate from the direction of the axis of the branch. The outgrowth of such extremely different, morphologically contrasted branches as those of Tetragraptus fruticosus, or T. taraxacum and of this Leptograptus from the identical type of proximal brachial thecae is certainly a strong argument for the propriety of viewing the changes within the branches as being of ontogenetic nature, and of corresponding phylogenetic importance.

Furthermore, the fact that the thecae within the same colony show a gradation from phylogenetically older to younger forms, and therefore, analogous to the organ of a growing individual, pass through ancestral stages, as, *e. g.*, do the septa of a cephalopod shell, demonstrates how closely the zooids of this colony were united into one organism, and that practically they were

more the organs of an individual than the component of a colony. Colonies are morphologically composite, but act physiologically as a unit. There are however all gradations from loose aggregates of individuals forming colonies to organisms in which, by division of labor, consequent supression of individuality and the presence of common organs, the colony also morphologically approaches closely to the character of a sole individual, e. g. the Siphonophora. Several important features of the graptolite colonies indicate that they also partook to a considerable degree of the character of a morphologic individual. This is specially suggested by the observation that several of the composite dichograptid colonies, as illustrated by the minute stages of Tetragraptus and Phyllograptus (fig. 18, 19), even in the earliest stages developed, by a rapid budding from the extremely small immature thecae (thecae are here meant to include or represent the zooids, which are not observable), the fundamental lines of the mature structure. This was possible because the buds are produced near the proximal ends of the mother thecae. Only afterward the thecae grew to mature size. This premature inauguration of the process of gemmation in individuals which have attained only a small fraction of their mature size, while reproduction in the animal kingdom takes place normally only in adult specimens, and the subsequent expansion of the whole stage, demonstrate that the early stages of these colonies did not grow by mere addition of buds, but also as entities. In the latter process, however, the thecae (zooids) appear entirely devoid of individuality and only as the subordinate parts of a whole growing body, which is then, certainly, to be regarded as a morphologic individual in so far as it grows as a unit or individual. The same uniform growth of the whole young colony took place also in Goniograptus, as the comparisons of the dimensions of

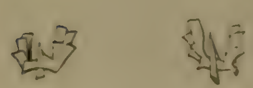

Fig. 18 Tetragraptus bigsbyi Hall. Minute growth stages. Sicular and antisicular views. x3½

Fig. 19 Phyllograptus ilicifolius Hall. Very young growth stage. x3

the youngest stages and of the resulting central parts of the later colonies will easily show.

It is significant that, as in the Siphonophora, the floating habit appears to have been principally instrumental in bringing about the development of other features suggestive of the morphologic individuality of the colony. Some of these are the presence of a common float or pneumatophor, observed in several groups, and the geometric arrangement of the branches, which becomes progressively more rigid, and which served to maintain the equilibrium and to give to the greatest number of zooids the most advantageous position.

If the graptolites so closely approached the morphologic value of an individual, it may be expected that, like an individual, the whole colony had its ontogeny and repassed ancestral stages. To these stages, as a glance at the regularly changing features of the growing colonies of Goniograptus will show, may be properly applied the terminology introduced by Hyatt for the ontogenetic stages of an individual.

The embryonic stage is clearly present in the initial part of the sicula, which, as Wiman has demonstrated, is differentiated from the distal part of the sicula by the nature of the periderm, which is thin, pellucid and possesses no growth lines. Holm[1] asserts his belief that this initial, more pointed end of the sicula "corresponds to the original chitinous covering of the free zooid germ or embryo." This initial part holds a position similar to the protoconch of the cephalopod shell. The nepionic or infantile stage is represented by the stages (fig. 1-6) in which the successive dichotomous divisions produce the stems. It begins with the formation of the apertural part of the sicula. The neanic or adolescent stage of the colony begins with the formation of the branches with serial arrangement of thecae and ends, in the Goniograptus material from the Deep kill, with the production of six such branches on each of the four stems. After this, in the ephebic or mature stage, the branches continue to grow out to full length. Distinctive

[1] Geol. mag. 1895. 2d ser. 32:435.

marks of the gerontic or senile age have not been observed in these colonies.

There is no doubt that to these ontogenetic stages of the hydrosome of Goniograptus there are corresponding phylogenetic stages in the evolution of the genus, though the forms leading up to Goniograptus and to the preceding multiramose dichogratids are not known, the latter appearing unannounced in the Cambric.

Parallel series of growth stages of other multiramose dichograptids have been obtained in the Tetragraptus and Didymograptus bifidus beds of the Deep kill section. As they serve more to verify the observations made on Goniograptus thureaui than to bring out new facts, their description has been deemed unnecessary in this preliminary publication.

DESCRIPTION OF A

FOSSIL ALGA FROM THE CHEMUNG OF NEW YORK

WITH REMARKS ON THE GENUS

HALISERITES *Sternberg*

BY DAVID WHITE

Plates 3, 4

Though scores of fossil bodies from the Devonic and Siluric in both Europe and America have been described and published as seaweeds, few of them are now generally regarded as vegetable, the greater number having proved to be of animal or mechanical origin. Even among those survivors whose outlines and superficial aspect would seem at once to proclaim their unity with this great class of lower cryptogams, a very small number only are wholly free from the suspicion that they should be relegated to the sponges or the graptolites, or accounted for as the burrows of some other organisms. The admitted identity of the small remainder of Paleozoic thallophytes is in most cases based on the internal organization of such fragments as are so fossilized as to reveal their microscopic structure, rather than on their form and external characters.

The unsettled and somewhat chaotic status of the supposed Paleozoic algae can not be due to any lack of seaweeds during Devonic or Siluric time. Plant life of this class must have been and undoubtedly was in great abundance. The apparent rarity of unquestioned Paleozoic algae is due in the first place to the absence of hard parts in most seaweeds and the consequent failure, except in extremely rare instances[1], of preservation of any portion of the plant, specially of fragments showing the essential primary diagnostic details relating to anatomy or reproduction. Another partial explanation lies in the remarkable similarities in form and habit between many algae and certain contemporaneous low animal types, specially among the sponges

[1] Chiefly in the coralline types.

and sertularians, whose structure was so much better suited to preservation as to establish a presumptive hypothesis that the resemblant forms must embrace the animal characters of structure and would not have been preserved but for the presence of the latter. Still another reason is the close resemblance of the impression of partially macerated algoid fragments to the markings, trails and burrows of organisms moving on or in the sea bottom. A final reason, and one undoubtedly not the least in importance, is the very great scarcity of specimens sufficiently complete to show at once the form of the individual while at the same time affording some hint as to its internal structure. The material described below includes two of these extremely rare and important examples.

The principal specimens described in this paper are exposed on a slab from the Chemung strata at East Windsor, Broome co., and presented to the state museum by E. B. Hall of Wellsville N. Y. The slab is of greenish gray micaceous sandstone, and is rectangular, being about 73 cm long, 32 cm wide and 1 cm thick. The lower surface (with reference to its original deposition) reveals the ferruginated remains of two or more striking and beautifully displayed algoid fronds, one of which (pl. 3) appears to be nearly complete. The lower end of the slab also reveals portions of four segments that may either belong to a single frond or to the same tuft. Evidence of current action and rapid deposition of sand is seen both in the dragging of the large frond, and in the burial of the basal and lower portions of all the fronds before the more distant segments were covered by the sand. Accordingly we see the fragments in another of the fronds traversing the entire thickness of the slab, while the basis of the segments is not represented on this slab, having been contained in the underlying rock. All the segments lying at the plane of cleavage of this surface of the slab show effects of current dragging in a direction slightly oblique to the longer diameter of the slab. In the fine fragment shown on pl. 3, the deformation is more pronounced, while in both the peripheral and the thicker portions the lamina show

signs of maceration. The result is a greater confusion and intricacy of the outlines as well as a partial obliteration of the same in the upper parts.

The fossilized fronds originally contained considerable carbonaceous matter which is now largely, though not wholly, replaced by oxids of iron. The normal aspect and habit of the segments is rather better represented by the frond on pl. 4 (fig. 1) though even here dragging and the diagonal position across the bedding as well as maceration partially conceal the form of the segments. The latter features are shown to better advantage in the fragments of still another frond preserved on the opposite (upper) surface of the same slab.

In all the fragments the depth of the impression, the evidence of thickness at the margin, the position and outlines of the branchlets in the compressed form and the amount of carbonaceous matter show that the substance of the fronds was thick and fleshy. At the same time a close examination reveals the presence of a narrow median strand generally appearing in low relief but sometimes as depressed. The fleshy character, the median axis and the form of division or habit of the frond appear to distinguish the plant in hand both generically and specifically from all other described forms of supposed Paleozoic algae. In this instance, as in so many other Paleozoic types, including many genera of ferns, in which the organs of reproduction are unknown, the generic classification necessary for the proper recognition and paleontologic treatment of the fossils is wholly artificial.[1]

The plant from East Windsor may be described as follows:

THAMNOCLADUS *gen. nov.*

Fronds ramose, alternately dichotomous from the base upward, more or less elongated; lamina fleshy, linear, convex or subcylindric, tapering gradually, and traversed by a central axis or strand.

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[1] The name proposed for this plant applies to the intricate copselike growth of the fronds and carefully avoids all implication of relationship to any particular family of living algae.

Thamnocladus clarkei *sp. nov.*

Pl. 3, fig. 1; pl. 4, fig. 1, 2

Fronds spreading, densely ramous, lax, pinnately and somewhat regularly dichotomous, intricate by reason of the repeated asymmetric divisions at intervals of 5–20mm; lamina relatively narrow, 1–7mm broad, thickest at the base, probably oval or subcylindric in section, narrowed slightly in each subdivision, the borders parallel, forking at a moderate or wide angle, and slightly recurved above each bifurcation, producing a graceful subflexuous form; central axis or strand slender, median or nearly so in the impressions, generally parallel to the borders, forking at a narrow angle a little below each dichotomy of the frond, tapering gradually upward, generally discernible throughout the greater portion of the flattened or macerated impressions, though often obscure in the basal portions or terete fragments.

One of the more important as well as conspicuous characters of Thamnocladus clarkei is its mode of division with a regularity and relative symmetry which, combined with the slightly divaricate attitude of the branchlets, results in a graceful flexuosity. The details of this habit which may be noted in the slender branches on the right on pl. 3 and pl. 4, fig. 1, are still more clearly seen in two isolated branches on a small slab[1] from Meshoppen Pa., shown on pl. 4, fig. 2. The more delicate segment in the latter beautifully illustrates the characteristic bifurcation and the gradual narrowing of the lamina with each successive subdivision. The width of the ultimate lobes is nearly the same, about 1mm, in all the examples. The Meshoppen specimens also indicate rapid sedimentation, since the lower portion of the fragment on the left completely traverses the slab, over 1cm thick, in an oblique direction. Its downward continuation was in lower strata. The central strand, while slightly clearer in the better preserved Meshoppen fragments is in precise agreement with the fronds from East Windsor.

The substance of the lamina in all the specimens has been reduced to a compressed carbonaceous residue which is mostly re-

[1] No. 25072 of the Lacoe collection, United States national museum.

placed by iron oxids. The rock is arenaceous and any expression of the structure is more or less obliterated by the coarse granular texture of the matrix and residue. In the lower portion of the segments this residue is obscurely marked in places, specially near the axis, by irregular longitudinal lines or striae; but neither these nor the rather indefinite strand seem to present a distinctly vascular aspect. The characters of the residue more strongly suggest the modified or pseudocompound structure of the more complicately organized algae, as in the stems of certain of the Phaeophyceae, rather than the vascular bundles or vessels of a fern.

Whether the fronds of Thamnocladus were borne on stipes is indeterminable from the material in hand, as is also the nature of the reproductive organs.

The distinction of Thamnocladus clarkei from other Paleozoic algoid forms from this country would seem a matter of little difficulty, as there are but few species which the plant in hand at all closely resembles. Buthotrephis gracilis Hall,[1] from the Trenton, is slender, flexuous, and slightly suggests the Meshoppen specimens, but the ramules are irregularly fasciculate, sometimes dilated upward, and generally as narrow near the base as at the top. B. subnodosa Hall[2] is also fasciculate. The aspect of fasciculation in Thamnocladus clarkei shown on pl. 3 and 4, is due to superposition, and is not a feature of the ramification. Even in these portions the central strand is generally visible in Thamnocladus. The fragment figured by Salter[3] as a "dichotomous rootlet" is somewhat suggestive of the American plant, though it is more rigid, narrow and distantly branching like some of the more slender examples referred to Psilophyton in America.

Thamnocladus is distinguished from Psilophyton by its lax, flexuous, dichotomous, bushy habit, the rounded or flattened

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[1] Pal. N. Y. 1847. 1: 62, pl. 21, fig. 1.

[2] —— 1: 262, pl. 68, fig. 3. This species is generally indistinguishable by any described characters from the group known in Europe as Palaeochondrites.

[3] Quar. jour. geol. soc. 1858. v. 14, pl. 5, fig. 3.

lamina, and the absence of the fernlike pinnate ramification along a rhachis found in the latter genus. Psilophyton is vascular and more or less distinctly fernlike in habit. Thamnocladus is as distinctly algoid in form.

Among the living algae there are numerous species in various families which present a more or less close superficial resemblance to the plants described above. So far, however, as the external characters, to which our knowledge is at present confined, are concerned the greatest similarity appears to be with the Fucaceae, though our plant also suggests some of the Dictyotaceae, specially Haliseris delicatula. It may be compared also with the red alga Stenogramma interrupta Mont.

The material in hand appears to contain but little to indicate a probable relationship of the supposed seaweed to the orders of living algae. With respect to its habit and the aspect of its more or less macerated lamina the closest analogies would seem to be in the fucaceous Phaeophyceae, though the possibility of a relationship with the higher types of Chlorophyceae should be kept in mind. Both of these great orders, together with the red algae (Rhodophyceae) appear with little doubt to have been represented by early types in the Devonic or still older formations.

The fossils of the species here described as Thamnocladus clarkei have generally been recorded in American literature under the name Haliserites dechenianus Göpp., to which the Meshoppen specimens shown in pl. D and their associates were referred by Lesquereux. The identification with the latter species is based on the original figures and description given by Göppert[1] in his great work on the *Flora of the Transition series*. The specific identity of the plant described above with a portion of the Old World material identified by various authors as H. dechenianus is pos-

[1] Fossile Flora des Uebergangsgebirges. Nova Acta Acad. C. L.-C. Nat. Cur. Sup. v. 22, Breslau and Bonn 1852. p. 88, pl. 2, fig. 1-6. First named in N. Jahrb. f. Min. 1847. p. 686.

sible; but, even with the most liberal interpretation of Göppert's diagnosis, it is doubtful whether our plant is admissible to the same species as the latter's types, while, as will presently be seen, its generic characters are entirely distinct from those of the badly confused and questionable genus Haliserites.

The genus Haliserites was established in 1833 by Sternberg[1] for algae with flat, membranaceous, costate fronds, with capsular sporangia grouped beside the costae in the lamina of the frond. The original (solitary) species proposed is Haliserites reichii[2] from the Cenomanian greensand at Niederschöna in Saxony. This, the type of the genus, was referred by Bronn,[3] in 1838, to the ferns and accordingly described as Chiropteris reichii (Stb.) on account of its superficial characters, in agreement with that genus of ferns, and its association with a dicotyledonous land flora. Schimper[4] assigned the species to the recent genus Delesseria, and Fuchs regarded it as a true alga, comparable to Fucus vesicularis; but Rothpletz[5], after examining the original specimen concludes that its association with a land flora is against its algoid nature, and that, though no lateral nerves are discernible, it would perhaps be better to inscribe the plant as Phyllites reichii. Still later, Newberry in his work on the plants from the Amboy clays of New Jersey[6] describes a type which he regarded as no doubt generically identical with Sternberg's Haliserites reichii, but for which, since it can hardly have been an alga, he proposes the genus Fontainea. It was considered by Newberry as closely related

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[1] Versuch einer geognostisch-botanischen Darstellung der Flora der Vorwelt. v. 2, fasc. 5 and 6, p. 34.

[2] Op. cit. p. 34, pl. 24, fig. 7. "Frons stipitata, dichotime bipinnatim ramosa, fere pedata, ramis ramulisque costatis, fere dimidiatis, latere nempe exteriore deficiente, ramulis oblongis, obtusis, subfalcatis, costis stipiteque teretibus."

[3] Lethaea Geognostica. 2: 576, pl. 28, fig. 1.

[4] Traité Paléont. Vég. 1:178.

[5] Zeitschr. d. deutsch. geol. Gesell. 1896. 48: 904.

[6] U. S. geol. sur. Monogr. 1895. 26: 95.

to Fontaine's Sapindopsis variabilis; and Prof. Ward[1] appears inclined to concur in this opinion. The plant from the upper Devonic of America evidently is neither congeneric with Sternberg's type nor in conformity with his diagnosis.

Since the virtual abandonment of Sternberg's original type, Göppert's species, Haliserites dechenianus, which presents a far closer resemblance to the living Haliseris (Dictyopteris) has generally been made to serve as the type of the genus not only among Paleozoic forms, but even among Mesozoic species.

The name Haliserites dechenianus was first applied[2] to a plant from the Spirifer sandstone, lower Devonic, of Nassau. With his final description of the species Göppert[3] quotes Sternberg's generic diagnosis verbatim. The Nassau species he describes as having flat fronds, alternately dichotomously ramose, the branches and branchlets linear, of equal width, and sometimes circinnate, the costae being median. The form and proportions of Göppert's plant, specially in the fragments shown in pl. 2, figs. 3 and 4 of his *Flora* are so similar to the corresponding features of Thamnocladus clarkei as at first to make it seem that the plants are specifically identical. Against this, however, stand the apparently membranaceous texture, and the generally sharply prominent costa, which even appears to be partially torn free in one[4] of the Nassau types. With these differences in mind it becomes apparent that, as artificial genera are commonly understood, Göppert's plant can hardly be considered as congeneric with that from Meshoppen except we conclude it was wrongly described, and that it is not membranaceous, not circinnate, and probably not flat.

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[1] U. S. geol. sur. Monogr. 1895. 26:96.

[2] N. Jahrb. f. Min. 1847. p. 686. Jahresb. d. Ver. f. Naturk. in Herzogth. Nassau. 1851. 7th Heft, 1st Abth. p. 141.

[3] Fossile Flora des Uebergangsgebirges. 1852. p. 88, pl. 2; *see also* Nova Acta Acad. C. L.-C. Nat. Cur. Sup. 1859. 27:442.

[4] Loc. cit. fig. 3.

The doubts which may arise as to the precise characters and nature of Haliserites dechenianus as described and illustrated by Göppert do not appear to be completely satisfied by reference to the interpretation put on it by other paleontologists. Most paleobotanists who have had to do with the species only in a casual way accept its algoid nature. Thus, Schimper[1] and Saporta[2] copy one or more of Göppert's figures while substantially reproducing his diagnosis under the same name. Among the authors who more carefully examined material there is difference of opinion. The Sandbergers, in their great work on the fossils of the Rhenish system in Nassau,[3] figure the species as a flat, membranaceous, more distantly bifurcating type with distinct slender median costae. The specimens, occurring at numerous localities supposed by the writers to be of Oriskany age, are described as having the lamina covered by a thin silky talcoid mineral, while the costa is converted to graphite. The form of the illustrated segments as well as the comments on the material appear to indicate an algoid type apparently congeneric with Göppert's, with which it was specifically identified. The specimen from the lower Devonic recently portrayed under Göppert's name by Potonié[4] appears to represent exactly the same form as that shown by the Sandbergers and seemingly belongs to the true algae, with which it is placed by the author.

In his *Fossil plants of the Devonian and Upper Silurian formations of Canada* Dawson[5] says: "there can be little doubt that the species Haliserites dechenianus Göpp., so abundant in the rocks of this age in Germany, is founded on badly preserved specimens of Psilophyton." Carruthers,[6] in agreement with Dawson, describes a number of apparently typical Psilophyton fragments from the Old Red sandstone of

[1] Traité Paléont. Vég. 1869. 1: 185, pl. 2, fig. 1.

[2] Monde d. Plantes. 1879. p. 172, fig. 2.

[3] Verst. d. Rhein. Schichtensyst. Nassau. 1856. p. 424, pl. 38, fig. 1.

[4] Lehrbuch d. Pflanzenpalaeont. 1899. p. 60, fig. 26.

[5] Can. geol. sur. 1871. p. 75.

[6] Seeman's jour. of botany. 1873. 2: 326.

Scotland as Psilophyton dechenianum, to which he refers Haliserites dechenianus Göpp., Lepidodendron nothum Salter, and Lycopodites milleri Salt. The synonymy of Psilophyton dechenianum (Göpp.) is much further extended by Kidston[1] so as to include, among others, Psilophyton robustius of Dawson, Lepidodendron gaspianum Dn. Hostinella hostinensis Stur, and the "plant" figured by Vanuxem[2] from the Hamilton beds near North New Berlin N. Y. Proceeding a step further, Malaise in agreement with other Belgian paleontologists inclines to the belief that Haliserites dechenianus represents the branches of Lepidodendron gaspianum Dn., a conclusion difficult to explain even on the assumption that Göppert's plant is a Psilophyton. Piedboeuf,[3] on the other hand, as the result of his studies of the fragments from the quarry in the Lenne shales (upper middle Devonic) in the vicinity of Gräfrath, on the lower Rhine, concludes that Haliserites dechenianus Göpp., Fucus nessigii, Dawson's Psilophyton, and Sphenopteris condrusorum Gilk. belong to a single fucaceous type which he calls Sargassum dechenianum. A fragment showing structure from the same quarry was studied by Solms-Laubach[4] who in 1894 described and illustrated it as Nematophyton dechenianum.

It is a long way from a taeniate, costate, membranaceous alga to a branch of Lepidodendron. So wide a variance in correlation can hardly be explained except by the supposition that some of the material submitted to the paleobotanists for examination had been wrongly identified or was misinterpreted by the writers themselves. Penhallow[5] in connection with the description of some Devonic plants from New York and Pennsyl-

[1] Cat. Palaeozoic Pl. Brit. mus. 1886. p. 232.

[2] Geol. N. Y. 3d dist. 1842. p. 161, fig. 40.

[3] Mitth. d. Ver. Naturw. v. Düsseldorf. 1887. Heft 1, p. 51.

[4] Jahrb. d. k. Preuss. geol. Landesanst. 1894 (1895). p. 88, 91, pl. 2, fig. 2-5.

[5] U. S. nat. mus. Proc. 1893. 16:108.

vania explains the discrepancy as due to confusion on the part of Göppert of Haliserites and Psilophyton at the beginning, representatives of both genera being included by him in the same species. Penhallow regards Haliserites as an alga which he defines as characterized by "Fronds plane, membranaceous, costate and dichotomous throughout; the more or less linear ramuli with simple terminations; sporangia in groups lateral to the midrib." As the true Haliserites dechenianus he describes and figures[1] a fragment[2] from Factoryville Pa. having the fronds regularly dichotomous at an angle of about 40°, the divisions linear, 3mm or more in width, equally and strongly costate throughout, with regularly wavy or ruffled margins.

From the foregoing it appears that the lower Devonic Haliserites of Göppert can not be regarded as congeneric with Sternberg's Cenomanian monotypic genus which is perhaps a dicotyledon; and that great uncertainty exists among paleobotanists as to the nature and characters of Haliserites dechenianus, it being regarded as a Psilophyton by some and as a taeniate, membranaceous alga by others. It is evident therefore that, whether Göppert's plant be one or the other, the name Haliserites can not, without violation of the common laws of nomenclature, be retained either for Psilophyton or for a genus of Paleozoic thallophytes.

For the flat, taeniate, costate, linear, regularly dichotomous, membranaceous algoid plant conforming to the genus Haliserites as defined by Penhallow[3] I would propose the name Taeniocrada.[4] The type species of the genus is Taeniocrada lesquereuxi, a specimen of which (no. 25164 of the Lacoe collection, United States national museum) was illustrated as Haliserites dechenianus in the 16th volume

[1] Loc. cit. pl. 10, fig. 6.

[2] 25164 of the Lacoe collection, United States national museum; from the Catskill at Factoryville Pa.

[3] Loc. cit. p. 112.

[4] The clause relating to the fructification should be omitted from the generic diagnosis, since the mode of reproduction of this and the allied species has not been observed.

of the United States national museum proceedings, pl. 10, fig. 6. This specimen, to which the above specific designation was applied in manuscript by the writer several years ago, is one of a suite from the Catskill beds at Factoryville Pa., now in the Lacoe collection. As will be seen by consulting the figure cited, the species is characterized by the wavy or ruffled lateral wing of the clearly membranaceous lamina, and the distinct costa, rounded in contrast but showing no signs of vascular structure. In form and aspect it is most nearly comparable to the living Dictyopteris delicatula Lam., though its lamina is wavy or ruffled at the borders in addition.

To the genus Taeniocrada would appear to belong also the specimens from the Devonic illustrated by Potonié[1] and the Sandbergers,[2] as perhaps may the Haliserites distans of Eichwald,[3] from the Carbonic of Russia, the H. lusaticus of Geinitz,[4] from the Permic of Saxony, and possibly the H. lineatus and H. chondriformis of Penhallow[5] from the upper Chemung beds at Lanesboro, Susquehanna co., Pa. Whether the specimens illustrated by Göppert as Haliserites dechenianus are congeneric with Taeniocrada, remains for the present a matter of doubt.

Of the plants from the Mesozoic described as Haliserites the H. contortuplicatus von der Marck[6] and H. gracilis Deb. & Ett.,[7] from the Senonian, are characterized as membranaceous and appear to owe their reference to this genus to their resemblance to the living Haliseris.[8] It is

[1] Lehrbuch d. Pflanzenpaleont. 1899. p. 60, fig. 26.

[2] Verst. d. Rhein. Schichtensyst. Nassau. 1856. p. 424, pl. 38, fig. 1.

[3] Lethaea rossica. 1860. 1: 49, pl. 1, fig. 2.

[4] Dyas. 1862. pt 2, p. 133, 336.

[5] U. S. nat. mus. Proc. 1893. 16: 110, pl. 11, fig. 8b and 9.

[6] Palaeontographica. 1863. 11: 81, pl. 13, fig. 13.

[7] Debey & Ettingshausen. Urweltliche Thallophyten. 1859. p. 61, pl. 1, fig. 1, 2.

[8] Other Mesozoic species described as Haliserites are: H. schlotheimi Debey (Entwurf. e. geogn. geogen. Darstell. d. Gegend v. Aachen. 1849. p. 31) and H. trifidus Debey (Verh. Naturh. Ver. pr. Rheinl. u. Westphäl. Jahrg. 5. 1848. p. 114) from the Senonian; H. tunguscanus Schmalhausen (Mém. Acad. imp. Sci. St Petersb. Ser. 7. 27: 59) from the Oolite; and H.? elongatus Fr. Braun (Münster's Beiträge. 1843. v. 6, no. 26, p. 26) from the older Mesozoic.

doubtful, however, whether, in the absence of knowledge of the frutification of the types, Cretacic and Devonic plants of this class should on account of a superficial resemblance be included within the same genus.[1]

The problem of the relationship of Göppert's types to Psilophyton or to the algae with membranaceous laminae seems to await thorough examination of the original specimens together with other material from the type locality or localities. It appears not improbable that Psilophyton will be found at the same stage and perhaps at the same localities. On the other hand it would not be strange if in the Psilophyton group, the doubts as to whose supposed structure were pointed out by Solms-Laubach[2], we should find transitional types between the algae and ferns and even other classes. And it should be borne in mind that such forms as Thamnocladus clarkei, while presenting the general aspect of many ordinary seaweeds, particularly among the fucaceous Phaeophyceae, and containing structural traces strongly suggestive of a somewhat highly organized axis, may eventually prove to be allied to Nematophycus (Prototaxites) or to some higher type.

The Devonic period offers a most fascinating as well as difficult field for paleobotanical investigations; and it has great need of ability and experience of the highest order to conscientiously and patiently work out the elements of its plant life, making the most of its generally scanty and obscure plant remains which must sooner or later throw the greatest light on the paleontologic origin of the ferns, equiseta, lycopods and gymnosperms.

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[1] It would seem that in such instances the ancient types should receive some distinctive name, such perhaps as was given to the Paleozoic forms of Chondrites which Schimper designated (Zittel. Handb. Palaeont. 2:61) Palaeochondrites.

[2] Jahrb. d. k. Pr. geol. Landesanst. 1894 (1895). p. 74, 77.

A NEW GENUS OF PALEOZOIC BRACHIOPODS, EUNOA

WITH SOME

CONSIDERATIONS THEREFROM ON THE ORGANIC BODIES KNOWN AS

DISCINOCARIS, SPATHIOCARIS AND CARDIOCARIS

BY JOHN M. CLARKE

Plates 5–8

While exploiting a section of the "Hudson river shales" near the village of Melrose, Rensselaer co. N. Y., in the season of 1901, Dr. R. Ruedemann uncovered a remarkable succession of graptolite faunas representing the associations of those organisms found and heretofore described by Hall and others from the shales of the Quebec formation at Point Levis and Ste Anne in Canada. Of this interesting occurrence adding in a very important measure to our knowledge of the ancient faunas of New York, Dr Ruedemann has already given a preliminary account in this report, with a summary of the variation and vertical distribution of the graptolites. These graptolite-bearing horizons, three in number in the section exposed, are black shales interbedded with green grits and gray sands, and, while they have produced graptolites in great profusion and variety, other organisms prove to be very infrequent; some small oboloids like Paterula, two specimens of a great Lingula, the largest known from the Paleozoic, which approaches in general features L. quebecensis Billings from the Point Levis section, and several examples of a very large shell in which we recognize an interesting new type of brachiopod structure and purpose to describe under the generic name

EUNOA

Inarticulate, subcircular, disk-shaped shells of discinoid expression. Brachial valve slightly convex with apex situated between the center and posterior margin of the valve; pedicle valve flat with wide open triangular foramen having its apex at the center of the disk and with margins rapidly diverging to the periphery. Shell thin, chitinous, phosphatic; surface with raised concentric filiform lines and finer radial intralaminar striae.

Eunoa accola *sp. nov.*

Shells of large size, outline normally subcircular or transversely subelliptic; under compression appearing somewhat squared by abrupt curves at the side. Brachial valve with low radial lines diverging forward from the apex and seen best when the test is slightly exfoliated. These are evidently, in part at least, traces of muscular scars similar to such as are frequently displayed by species of the genus Orbiculoidea. The shell around the apex may have been continuous, but some specimens indicate an obscure and short peripheral notch or incurvature on the posterior edge.

In the pedicle valve the cleft is wide, and its apex nearly central. The edges of this cleft show convergent, thickened shell ridges, which lie just within the margins and unite at some distance in front of the apex, becoming thicker and more highly raised, thence continuing forward for a short distance as a single ridge, which soon fades out on the pallial surface. In the existence of these muscular fulcra we find again a parallel condition to that seen in many orbiculoids.

The shell substance is highly tenuous but seems to show a subdivision into two layers. Doubtless here, as in the cases of such brachiopods elsewhere observed in bituminous shales, the original lime content of the shell has been lost in fossilization; however, this lime content must have been slight and greatly subordinate to the phosphatic element.

These shells are all large, indeed the species is one of the largest of the inarticulate brachiopods. On bringing this genus into comparison with known allied genera, we observe that its differentials from those are as follows.

In Orbiculoidea, the wide open pedicle cleft is an embryonal and nepionic condition in all species where the ontogenic development has progressed normally. In Schizocrania it is a normal adult phase, but Trematis is a heavier lime-shelled genus with other differentials expressed in the submarginal apex of the brachial valve and in the ornament of the surface. Trematis likewise maintains the open foraminal fissure

but this is less primitive than in Schizocrania, its margins curving toward each other and approximating at the periphery. These two genera are early (lower Siluric) and phylonepionic expressions of Orbiculoidea. In Schizobolus (middle Devonic) the pedicle passage is a very short triangular notch, and the genus is a late survival of the primitive stage represented by Eunoa.

Trematobolus, Schizambon and Schizotreta are conditions in which the pedicle has not only become inclosed but also insheathed by a short tube.

The generic characters of the genus Eunoa are thus well defined, and no other shell carries so primitive an expression of the orbiculoid type, a highly phosphatic shell, simple, wide, triangular pedicle cleft and unmodified concentric surface ornament.

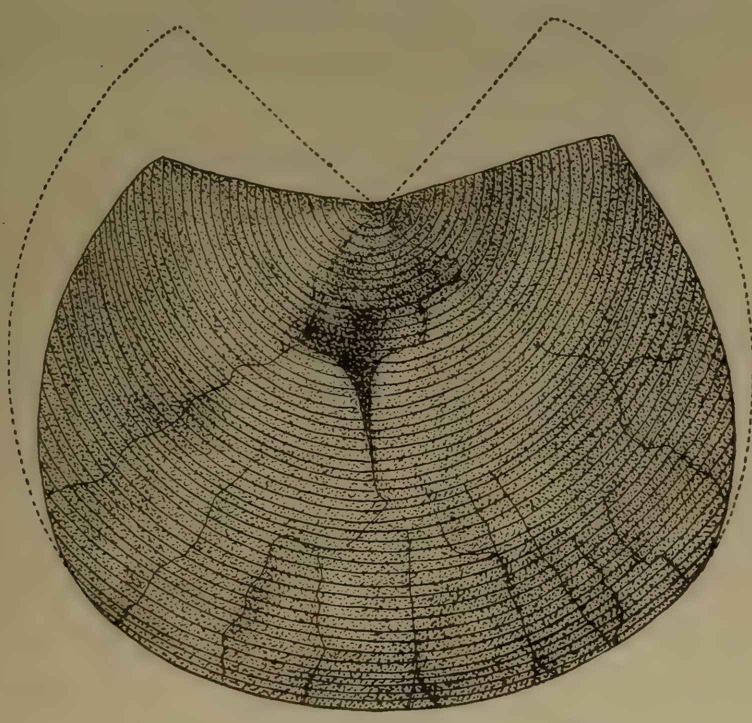
Horizon and locality. In graptolite shales of the age of the Beekmantown limestone, on Deep kill near Melrose N. Y.

Observations. The striking similarity of this organism to that described by Jones and Woodward from the Moffat shales of Dumfriesshire as Discinocaris gigantea leads to a few remarks which are naturally suggested by this resemblance.

Moffat series. The Moffat series of Dumfriesshire which has been described in great detail by Lapworth[1], is constituted of black bituminous shale bands with interbedded grits, the former carrying extensive graptolite faunules with such forms as Monograptus, Dicranograptus, Climacograptus, Dicellograptus, Pleurograptus, Leptograptus, Thamnograptus and many other genera which are present in the Deep kill section. Lapworth has found evidence for regarding the comparatively slight thickness of these beds as a sedimentary equivalent in the section where they occur, of the Siluric series from the middle of the Llandeilo up to the Wenlock, basing this deduction chiefly on the range and limitations of the graptolite faunas. There is herein a condition clearly parallel to that now determined for the Hudson river beds of eastern New York, whose graptolites have

[1] *See* specially Lapworth. The Moffat series. Quar. jour. geol. soc. 1878. 34:240–346.

fairly demonstrated their equivalence to sediments elsewhere extending from the middle Trenton upward to the top of the Lorraine shales. From these Moffat beds and in association with some of the graptolites, Prof. T. R. Jones and Dr H. Woodward have described a number of circular shields of chitinous substance, concentric markings and triangular cleft, as crustaceans under the name of Discinocaris. The type species of this group of putative phyllopods is D. browniana; and among them is the large shield to which we have referred, Discinocaris gigantea. Examination of the figure with restored outline given by these authors, which we reproduce here, shows



Discinocaris gigantea after Jones and Woodward

evidence of the convergent internal ridges showing through or impressed on the surface ornament and corresponding to these well marked muscular characters in Eunoa. This specimen is apparently the most nearly entire of any recorded; but the authors note that fragments of these bodies indicate a diameter of fully 7 inches. That Eunoa is a brachiopod of which we have both valves is beyond contest; and that Discinocaris gigantea, occurring in homotaxial rocks of similar character formed under like bathymetric conditions and with

similar organic associates, is also a Eunoa seems altogether certain.

This fact leads us to some further comment on the nature of other species of Discinocaris and similar bodies which have been described as phyllocarid crustacea, but whose nature has still to be satisfactorily demonstrated.

The organic bodies called Discinocaris, Spathiocaris, Cardiocaris, Pholadocaris, etc.

These organisms are all thin, chitinous, tenuous, oval, or cordate shields, bearing a deep triangular slit at one end extending back to the apex of the shell, about which the growth lines are concentric. These bodies abound at certain Devonic horizons, and some of allied form were early observed by F. Roemer and de Verneuil, who, familiar with the aptychi of the Ammonites in the mesozoic, designated them without attempt at closer investigation, as aptychi of the Goniatites.

Discinocaris was described by Woodward; and, though its forms, of which a number have been named, are in the features mentioned above not materially unlike the Devonic objects Spathiocaris and Cardiocaris, they are for the most part from horizons which long antedate the appearance of the goniatites. We have shown that one is evidently a brachiopod of large size, but this is one of the most recently described species referred to the genus.

The genus Spathiocaris was described by the writer. Following H. Woodward's determination of D. browniana etc. as crustaceans, Spathiocaris (Naples fauna) was also referred to this group of organisms.

Soon after describing the genus (S. emersoni), the writer referred similar bodies from the Devonic at Bicken, Westphalia, to Spathiocaris and Cardiocaris, regarding them as crustacea. Kayser at about the time of this publication, had discovered and described some of these bodies from Bicken as occurring in, though not well fitting, the body chamber of the goniatite, Manticoceras intumescens. Similar occurrence was noted by Woodward in a goniatite from

Büdesheim. Dames vehemently contended that none of these bodies was crustacean, that all their characters pointed to their function as operculums of goniatites, so far as goniatites existed at this time, and, as for the rest, their nature was unknown. Woodward, subsequently reviewing all the evidence, admitted that some of the bodies were of goniatite nature, but concluded from analogy with such shields as Peltocaris (lower Siluric), in which the triangular cleft was indubitably covered with a rostral plate, that the others were rationally ascribable to the crustacea.

The latest observations on these bodies are those of Holzapfel supplementary to his description of the Goniatites of the *Domanik schiefer.* It was from these shales that de Verneuil described the first known of these bodies as aptychus of a goniatite. Holzapfel, in rehearsing all the evidence in more detail than is given in the foregoing and without attempting to enter upon an analysis of possible crustacean structure, concludes that at any rate Spathiocaris and Cardiocaris were not aptychi or ammonoid operculums. That they may not have had some other function in the ammonoid body, he is not disposed to deny. From so high an authority on the structure of the goniatites this opinion carries much weight; and Holzapfel reiterates the statement by de Verneuil that these bodies occurring in the black layers of the Domanik schiefer are not immediately associated with goniatite shells.

The writer has repeatedly drawn attention to the same feature of the occurrence of these bodies in the Naples and Genesee beds of New York, where, after 25 years of search and the acquisition of hundreds of spathiocarids, in no instance has any specimen been observed in association close enough to suggest, of itself, any relation to the ammonoids. We are now speaking of the singly cleft shields, such as have been in two recorded instances found within the goniatite chambers in the limestones of Germany, as above referred to.

Here is evidence of affinity which points both ways. To prove these bodies opercular shields or covers for any other parts of

the cephalopod body, the following obstacles must first be cleared away: 1) They are usually completely dissociated from the cephalopod shells. 2) Some forms of Discinocaris and Peltocaris of the early Siluric are virtually indistinguishable save for outline and size from Spathiocaris and Cardiocaris of the Devonic. The former appeared at a time long antecedent to the ammonoids. We know that one of those early species was brachiopodous, the others are not goniatitine; the later forms can hardly match our conception of brachiopod structure. Objects of so similar a character would *a priori* be of similar nature, an argument which, if carried to a logical conclusion, would wreck the inferred goniatitine character of the Devonic genera. In meeting these obstacles it is to be borne in mind that no single specimen of any of the genera Discinocaris, Pholadocaris, Spathiocaris, Cardiocaris has been proved crustacean. The segments and spines referred to these may or may not have any relation to the shields themselves.

There is a series of these shields which is unlike those specially mentioned above, in having a triangular cleft at both extremities, that behind not reaching to the apex or growth center of the surface, but often broader than the anterior cleft. These are wholly Devonic objects and have been termed by the writer Dipterocaris. American specimens have been found not so much in the bituminous layers of the upper Devonic as in the flags and sands, and certain specimens have clearly indicated that in uncompressed condition the contour was distinctly sloping from the bridge between the two lateral wings of the shield. Among these specimens there is no room for any suspicion that they have brachiopodous affinities. Regarded as crustacea, that is Phyllocarida, at the time of the description of the genus, the crustacean similarities are indeed more strongly marked than in the Spathiocaris class of shields, a feature specially brought out on comparison between such a Dipterocaris and the carapace of a phyllocarid like Rhinocaris or Mesothyra; but on the other hand the general form, structure and surface characters of all these

bodies (specially Devonic bodies) are so much alike that whatever course of argument applies to one seems of necessity to apply to the rest, the more as they are concurrent in the rock strata. Yet in these bipartite shields we find a closer analogy, if any, to the ammonoid aptychi of the Mesozoic, so far as the division of the shield is concerned. It has been argued by various writers that the tenuous chitinous substance of these bodies is purely a result of preservation. Calcareous substance is frequently destroyed in bituminous shales; hence the calcareous layers of these bodies may have been thus removed, leaving only the organic film. Specimens from the sandstones are however equally devoid of trace of calcareous layer. It has furthermore been contended that these presumable aptychi, on the decomposition of the animal's body, have been floated by the waves unable to transport the heavy shells, and have hence been accumulated by themselves in other sediments than the latter; a plausible contention could we but find some more satisfactory ground in the structure of the "aptychi" for ascribing this cephalopod function to them.

In the *Paleontology of New York*, v. 7, we figured the sole instance known from the rocks of this state of the concurrence of any of these bipartite bodies with a goniatite. Here is a specimen from the soft Naples shales, presenting a body whorl of Manticoceras pattersoni, the diameter of whose shell originally was not less than 3 inches. On and within its body chamber lies a Dipterocaris or at least an object having the doubly cleft outline of the species so denominated. This little body has a length of about 5 mm. This concurrence may, of course, be quite as casual as the usual dissociation of these bodies. If, however, this be taken as an indication of relationship between the ammonoid and the Dipterocaris, it is not the relation of aptychus or operculum. However, in view of all the present evidence, we can not divest ourselves of the belief that there is nevertheless some organic connection between these Devonic bodies and the cephalopods; for, while we lack any further confirmation of the latter than that above

given, we have been altogether unable to acquire positive indication of crustacean structure in any of them.

In this connection I take opportunity of referring to a body from the upper Devonic, which has the aspect common to all these genera, the tenuous shield concentrically striated, but a size which greatly surpasses them. On an accompanying plate is figured such a specimen taken from the upper layers of the Portage group in the Tannery gully at Naples, a horizon which has produced a number of singular objects, Paropsonema cryptophya, some undescribed gephyrean worms and other unrecorded occurrences. This object is one half of a singly cleft shield resembling a circular Spathiocaris or Cardiocaris.

In the collections of the state museum there has been for many years a plaster cast, and among the archives a pencil sketch, of a large discinoid body taken from the Ithaca beds of the upper Devonic (Portage stage) at Truxton, Cortland co., both cast and drawing sent to the late Prof. Hall by the late Rev. H. A. Riley of Montrose Pa., a well known collector and student of fossil organisms. It will be observed from the accompanying figure of this body that the furrow which crosses the surface of the body is accidental, not natural, as it not only divides the body into unequal parts but is crossed by the concentric rings of growth. The body was originally depressed conical, as shown by the irregular wrinkling of the surface under compression, the beak being well forward of the center and the concentric lines conspicuous but not relatively so to the size. The dimensions of this object are specially noteworthy; fore and aft it was not less than 5 inches long and transversely through the center nearly 6 inches. The Naples shield has just about the same dimensions. Either of these bodies by itself fails to explain its true nature; taken together, I am disposed to believe that all the evidence indicates that the one is probably the correlate of the other, one a pedicle valve, the other a brachial valve of a great inarticulate brachiopod like Eunoa. We should probably go astray in identifying this great shield generically with Eunoa from the Melrose graptolite beds; and in view of

Orbiculoidea magnifica

Upper or brachial valve

Since this article was put in pages the specimen here figured has been obtained from the Tannery gully at Naples, the same locality and horizon which furnished the folded pedicle valve shown on plate 7. The presumption made in the paper that that body appertained to a discinoid brachiopod is thus fully justified by this recent acquisition.

the fact that there is no structural character which distinguishes the shell from the genus Orbiculoidea, we propose to term it provisionally O. magnifica, in the hope that this brief notice of the object may draw the attention of collectors to it as one of which we seek further information.

STRATIGRAPHIC VALUE OF THE PORTAGE SANDSTONES

BY D. D. LUTHER

James Hall, in his *Report on the survey of the fourth geological district of New York*, 1843, p. 24, thus described, under the caption "Portage or Nunda group", the strata succeeding the Genesee shales in the valley of the Genesee river:

> This group presents an extensive development of slate, shales and flagstones, and finally, some thick bedded sandstones toward the upper part. Like all the other mechanical deposits of the system, as they appear in New York, it is extremely variable in character at different and distant points. . . From its superior development along the banks of the Genesee river in the district formerly included in the town of Nunda, now Portage, it has received that name to distinguish it from the higher rocks, which possess some differences in lithological characters, but a more striking dissimilarity in organic remains.

On p. 226, he says: "On the Genesee river this group admits of the several subdivisions shown in woodcut 97, which are, in upward order 1) Cashaqua shale, 2) Gardeau shale and flagstones, 3) Portage sandstones."

The footnote accompanying the woodcut says: "As we go east from this point, however, there is a constant increase in arenaceous matter, and in a westerly direction an increase of mud or shale."

The strata that compose the Portage group as thus defined are exposed almost continuously in the sides of the deep canyon of the Genesee river from near its opening into the wide valley near Mt Morris, to the top of the cliffs on the south side of the high railroad bridge at Portageville, a distance of 15 miles in a direct line, and about 20 along the tortuous river channel. The difference in elevation between these points is 680 feet, and the dip adds 381 feet to the rock section; total thickness 1061 feet.

The Cashaqua shale was described as a "soft argillaceous rock of a green color . . . it contains flattened concretions of impure limestone and sometimes of sandstone, but of these it contains no continuous layers." It is favorably exposed 6 miles east of the Genesee gorge on Cashaqua creek and can be easily traced westward to Lake Erie and eastward to Seneca lake; throughout the entire distance it is found to overlie a bed of black shale in which fossils are exceedingly rare. In the river section this bed is about 35 feet thick. This has been termed the lower black band and is continuous and well defined from the Naples valley on the west to Lake Erie, increasing slowly in thickness.

Next below, and overlying typical upper Genesee shale, are 4 to 6 feet of lighter colored shales and a few thin flags, the whole bearing a much closer clastic and paleontologic resemblance to the Cashaqua shales than to the dark gray shales bearing Lunulicardium fragile abundantly, on which they rest.

Overlying the Cashaqua beds occurs another thick mass of densely black slaty shale, known as the second black band. It is of the same character as, and coextensive with the lower mass and like it increases in thickness toward the west, while the Cashaqua shales decrease in that direction. These two black bands are bench marks in the stratigraphy of the Portage sections as their character is maintained and they are easily recognized for more than one hundred miles east and west of the typical section, while the other beds are variable in character and not to be distinguished without much care and study.

The second of Hall's divisions, the "Gardeau shale and flagstones" was described (p. 227) as "a great development of green and black shales with thin layers of sandstone." It includes the second black band which is its basal stratum. The upper limit was not definitely given, as the only change noted in the character of the sedimentation is the increase of arenaceous matter toward the top. "Towards the upper part the courses

of sandstone become too thick for flagstones and the shale is in thicker masses than below" (Hall, p. 228).

About two thirds of the strata comprised within the typical Portage section are represented by this middle division, the base of which is at the river level at the lower end of Smoky hollow, about 5 miles above the mouth of the gorge at Mt Morris, 613′ A.T. The upper limit, which for the purposes of this paper is assumed to be about 27 feet above the crest of the upper fall at Portage (1082′ A.T.) is 506 feet higher than the base, and the southward dip adds 208 feet, making a total of 714 feet for the thickness of the Gardeau division.

With regard to the Portage sandstones, Dr Hall said on p. 228 "The thick bedded sandstones at Portage form the terminal rocks of the group. . . The upper part consists of thick bedded sandstones with little shale, while below the sandy layers become thinner, with more frequent alternations of shale."

There are 182 feet of strata embraced in the section between the assumed base 27 feet above the upper fall and the top of the cliff south of the bridge and on the east side of the river. A layer of hard blue shale, 2 feet thick, occurs 12 feet above this assumed base, and another of similar character is found 52 feet higher; very thin shaly partings also separate some of the harder layers, but with these slight exceptions the formation consists of layers of light bluish gray, medium fine grained sandstone from 2 to 10 feet thick. The character of the rock is remarkably uniform, varying but slightly in the degree of hardness, some layers showing a tendency to be schistose or flaggy; occasional concretions occur.

"The Portage sandstone is succeeded by olive shaly sandstone and shale and this by black micaceous slaty shale with septaria; to this follow shales and coarse sandstones with fossils of the Chemung group" (Hall, p. 248). These beds are not exposed along the river but the lower portion may be seen in the ravine of Wolf creek below Hopkins's mill at Castile, and the upper part in the ravine of West Coy creek at Wiscoy, and in

several ravines on the east side of the upper Genesee valley opposite Fillmore.

These beds which cap the Portage sandstones and still retain the characteristic species of the rocks below have been termed by Clarke the Wiscoy beds. They are composed mainly of soft shale, bluish and argillaceous, or olive and sandy, with occasionally thin black layers, a few flags or thin sandstones and calcareous concretions.

They are terminated by a band of flags and thin sandstones that appear in the north wall of the ravine above the falls at Wiscoy, and in the sides and bottom of the river channel a mile south of Fillmore where they form "Long Beards riffs."

These latter sandstones are about 150 feet above the Portage sandstones and are the lowest "coarse sandstones with fossils of the Chemung group" that have been found in the immediate vicinity of the Genesee river. They are succeeded by nearly 300 feet of shales and flags and these are overlain by the heavy Rushford sandstones, exposed in the hills west of Caneadea. Chemung fossils are common through this mass of shales and sandstones.

The Portage sandstones in the Genesee river are therefore separated from any lithologically similar formation for 450 feet above and none of like character of sufficient thickness to cause confusion in correlation, occurs below.

Recapitulating, the subdivisions of the rocks of the Portage group in this section, that by their individual characteristics, their homogeneity and their thickness are so well defined that they may with safety be used in correlation with other local sections, are: the lower black band, 35 feet, the Cashaqua shale, 130 feet, the second black band, 52 feet, the Portage sandstones, 182 feet.

Besides these, there occurs in the lower part of the Gardeau beds, interstratified between beds of shale, a band of flags and thin sandstones aggregating about 25 feet in thickness, that becomes a more distinct feature in the stratigraphy toward the east, and will be referred to again in this paper.

The character of the fossils in this group of formations has been fully discussed by Clarke. The fauna of the Portage series as a whole is highly distinctive and not to be confused with that preceding or with the Chemung fauna which follows. The latter is specially characterized by prevailing brachiopod types, a group almost wholly wanting in the Portage, and *per contra* the peculiar lamellibranchs and cephalopods of the Portage are not carried over into the Chemung fauna save as one species or another may have survived the general invasion of the Chemung fauna from the east.

In the town of Naples, about 30 miles east of the Genesee river the upper beds of the Genesee shale, all of the Portage divisions and several hundred feet of lower Chemung strata, in the aggregate not less than 1500 feet, are abundantly exposed in the numerous ravines and rock escarpments about the south end of the Naples valley.

In the strata above the Genesee shale the proportion of sandy sediment, in the shape of flags and thin sandstones is noticeably greater than in the Genesee river section, and the thickness of the subdivisions is not the same, still the differences in lithologic character are so small, that no difficulty is experienced in distinguishing the several subdivisions as previously described.

The upper beds of the Genesee, succeeded by the band of lighter colored shales and flags, and next above, the lower black band are exposed along the road leading westward on the Naples-Bristol town line near Woodville and near the mouth of the Snyder gully, $\frac{1}{8}$ mile south.

The top of the Genesee shale in the road west of Woodville is 751′ A.T. This point as indicated on the Naples sheet of the topographic map is on the line of 42° 40′ which crosses the Genesee river 5 miles south of the mouth of the gorge at Mt Morris and almost exactly at the place where the top of the Cashaqua shale dips below the river level, which is here 602′ A.T. The top of the Genesee shale at Woodville is therefore the difference in levels, 149 feet, plus the thickness of the

Cashaqua shale on the river section, 165 feet, or 314 feet higher than it is on the Genesee river, thus showing an average eastward elevation or pitch of $10\frac{1}{2}$ feet a mile.

The Cashaqua shale is abundantly exposed in a large number of ravines that score the hillsides between Canandaigua lake and the village of Naples. The beds are quite sandy, flags being common and a few layers of sandstone reach a foot in thickness. The upper part is more argillaceous and calcareous than the lower, and it is also more fossiliferous, the characteristic fossils of the group being quite common in the softer shales.

The second black band, less than half as thick as in the Genesee river section, but well defined and easily distinguished is exposed in the same ravines, and also in the rock cut on Rhine street, and at the foot of Hatch hill, opposite the village of Naples, where it dips under the water of Naples creek at about 775′ A.T.

Abundantly exposed at the foot of Hatch hill, and in the upper parts of the ravines at the north, but much better in the Tannery gully, 1 mile south, and the Grimes gully $\frac{1}{2}$ mile west of the village, there are about 300 feet of shale and flags that correspond very closely, both in structure and fossils, to the Lower Gardeau beds as they appear in the escarpments between Smoky hollow and the top of the upper Portage fall. The shales are black, bluish or olive, in all varieties, and the sandstones light bluish gray with different degrees of hardness. At some horizons the proportion of arenaceous matter is very small, while at others it is equal to the argillaceous.

At the top of these beds, and about 600 feet above the Genesee shale a series of sandstones, varying in thickness from an inch to 8 feet, and separated from each other by thin shaly partings, and aggregating about 50 feet thick, produce the third falls in the Grimes gully, the High falls in the Tannery gully, and prominent escarpments on the sides of Hatch hill and West hill. They are known as the Grimes sandstones. Their most southern exposure is on Olney brook at the waterworks reservoir $1\frac{1}{2}$ miles south of Naples, at the elevation of 975′ to 1025′

A.T. Though the individual members of the series frequently change in character and sometimes pinch out entirely within short distances the formation as a whole is continuous for many miles toward the east and west. As the subjacent and the overlying beds are composed almost entirely of soft shale the sandstones usually produce falls where a hillside stream crosses this horizon and make more or less well defined escarpments on the sides of the valleys.

The proportion of sandy sediment in the Grimes sandstones as in the flag and shale beds below, is much less in the river section, but the formation maintains its character sufficiently to be noticeable as a distinct band of flags and thin sandstones in the cliffs on the east side of the river at St Helena, and also 1 mile southwest, where it comes down to the river level near the mouth of Wolf creek, almost exactly west of the exposure at the reservoir in Naples, at the elevation of 675′ to 700′ A. T.

Up to the base of the Grimes sandstones the similarity in both lithologic and paleontologic aspects of the two sections makes correlation simple but at this horizon, in the Naples section, the Portage fauna suddenly and finally disappears, while in the Genesee section it holds its place to the exclusion of all brachiopods to a horizon that, stratigraphically, is 700′ to 800′ higher.

The last appearance of the normal Portage fauna in the Naples section is in some thin layers of soft shale between flags, in the face of the precipice at the third falls in Grimes gully, and this fauna is found also in similar shales at the same horizon in Tannery gully at the High falls.

24 feet higher and 9 feet below the crest of the falls a 4 inch layer of soft sandstone contains Liorhynchus quadricostatus, Atrypa reticularis, Productella speciosa, Ambocoelia umbonata var. gregaria, Leptostrophia mucronata and Orbiculoidea sp., an assemblage regarded by Clarke as altogether foreign to the Portage or Naples fauna. These fossils are found along the line of outcrop of this layer for four or five rods on both

sides of the cascade but nowhere else in the valley at this horizon. This layer is 600 feet above the Genesee shale.

The Grimes sandstones come in in full force 4 feet above this layer and are well exposed in the floor and sides of the canyon above the falls, but appear to be barren of fossils. They are exposed in a similar manner at the top of the High falls in the Tannery gully. No fossils are found here at the base of the sandstones but near the middle of the beds an extensive lenticular layer a foot thick is composed principally of crinoidal segments and comminuted brachiopods and shows a few specimens of Liorhynchus, Atrypa, Productella, Ambocoelia umbonata and a small Chonetes in a recognizable condition.

This calcareous lentil extends 60 to 80 rods toward the north and outcrops slightly in the fields on the north side of the road leading up Hatch hill. A few feet higher occur species of the dictyosponge Hydnoceras with Paropsonema cryptophya, a large Orbiculoidea and other problematic organisms not elsewhere seen. A Leptodesma of notable size and not seen in the beds below occurs in the lower part of the Grimes sandstones in the small Smith ravine south of the Tannery gully and also in a field outcrop in Nellis's pasture 1½ miles northeast of the village. The same fossil appears on the surface of a thin sandstone about 50 feet above the Grimes sandstones in the Lincoln gully on the opposite side of the valley. Sponges, crinoids and a few brachiopods have been found in these sandstones at several other outcrops in the valley.

The Grimes sandstones are succeeded by shale, flags and thin sandstones in varying proportions for about 600 feet to the base of the High Point sandstones. Very few of the harder layers reach a foot in thickness and no distinctly sandy band is of sufficient magnitude to assist or confuse in the determination of horizons. No layers have been found to be continuously fossiliferous, but many of the sandstones and a few of the shaly beds contain fossils quite abundantly for a short distance.

Of the fossils observed in the strata between the Grimes sandstone and the High Point sandstone the following are noteworthy.

The state museum record numbers attached to the species named signify localities in these layers as follows:

2429 Above Damm's vineyard, West hill
2430 Above Cleveland's, West hill
2431 Above Freed's, West hill; 250 feet above Grimes sandstone
2432 Worden hill, South Bristol, 200-300 feet above Grimes sandstone
2433 Roadside near Charles Sutton's, West hill, Naples
2434 West Italy, Yates county
2435 Powell hill, 2½ miles north of Naples; 250 feet above Grimes sandstone

Ambocoelia umbonata, 2430, 2431, 2432, 2433, Deyo basin 250 feet above Grimes sandstone
Spirifer mucronatus var. posterus, 2431, 2433, Deyo basin
S. mesastrialis, 2432.
S. disjunctus, Deyo basin
Stropheodonta cayuta, 2431, 2432
Schizophoria impressa, 2431
Atrypa hystrix, 2431, 2432, Deyo basin
Productella lachrymosa, 2432, Deyo basin
Liorhynchus mesacostalis, 2433
Grammysia elliptica, 2430, 2433
Cimitaria corrugata, 2430
Leptodesma robustum, 2431
Palaeotrochus praecursor, 2432
Hydriodictya cylix, Deyo basin
Ceratodictya annulata, Deyo basin
Hydnoceras tuberosum, 2434
H. variabile, Deyo basin
Arthracantha depressa, 2429, Deyo basin

The flags and shales in which these brachiopodous faunules are found are stratigraphically equivalent to that part of the Gardeau flags and shales exposed on the Genesee river between Wolf creek and the top of the upper Portage falls. Structurally they differ very little from the undoubted Portage beds below, or the equally unquestioned Chemung strata above them.

Lithologically and stratigraphically the 600 feet of strata between the Grimes sandstones and the High Point sandstones can be correlated only with that part of the Portage section termed Gardeau, but paleontologically they bear no trace of the Portage or Naples fauna and on the other hand an abundant presentation of the Chemung fauna with the exception of a few feet of deposits at the base of the Grimes sandstones which represents an outrunner from the Ithaca fauna farther east.

At the top of these beds the proportion of arenaceous matter increases gradually and a band of heavy sandstones occurs in a stratigraphic position corresponding to that of the Portage sandstones at Portageville. The outcroppings of these sandstones about Naples are found at or near the tops of the hills in the vicinity and 900 to 1000 feet above the valley.

As the exposures are isolated from each other, and not extensive, none having been found that present an entire section of the formation, accurate measurement of the strata composing it is not practicable, but the heavy layers of sandstone are prominent in the bedding for 150 to 200 feet, closely resembling the Portageville rocks, but more frequently separated by beds of shale. The largest and most favorable exposure is in the cliff at High Point 2 miles west of Naples, at the elevation of 1700′ to 1800′ A. T., where about 75 feet of the sandstones and shaly partings appear in place in the escarpment and large blocks are scattered over the immense talus.

Situated about the middle of the section exposed is a calcareous lens 5 feet thick at the center, and 25 rods in breadth, composed almost entirely of fossils, of which 33 species have been identified (United States geological survey, Bulletin 16), 24 being brachiopods, none of which so far as known have been found in the Portage section on the Genesee river, nor below the Grimes sandstones in the Naples section. This constitutes the interesting High Point fauna which has been elsewhere described and shown to carry a marked representation of species present in the upper Devonic faunas of Iowa.

The diagram on the following page indicates the relative positions of the more interesting of the line of outcrops that show these High Point sandstones (station 1) to be synchronous with the Portage sandstones at Portageville (station 14).

Station 2. Wolf gully 3½ miles a little west of south from High Point. An escarpment at the top of the west bank is 30 to 40 rods long and shows 35 feet of rock mostly heavy sandstones. No fossils have been found here.

Station 3. ½ mile east of station 2, on the east side of Frink hill. An escarpment in which is a thin calcareous layer, composed principally of crinoid stems and bryozoans. Contains many brachiopods.

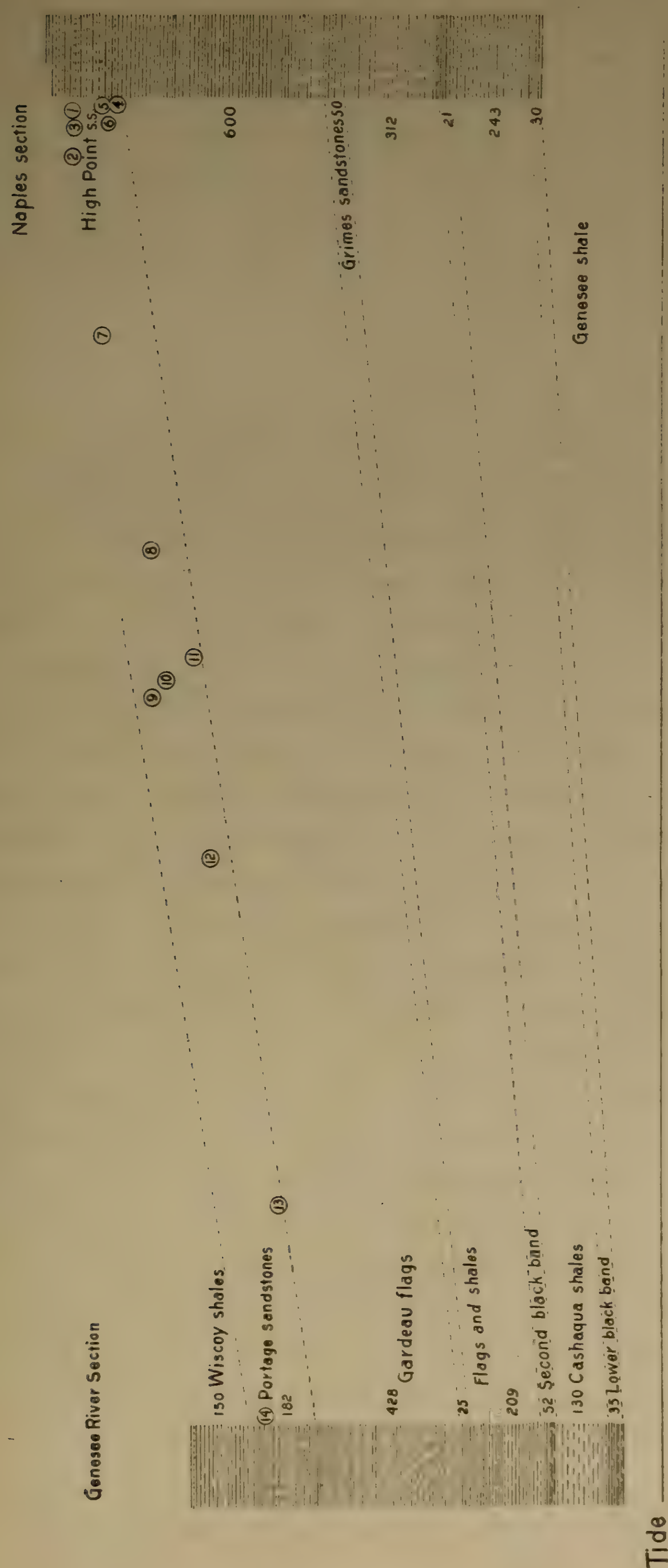
Station 4. Ledges on the west side of Knapp hill, 4½ miles southeast from High Point. A calcareous concretionary layer is crowded with D. t u b e r o s u m and Chemung brachiopods.

Station 5. One mile east of station 4 the sandstones appear in several small escarpments on north slope of Pine hill.

Station 6. McClarries's quarry on the hillside east of the village of North Cohocton. About 30 feet of light blue gray compact sandstones in heavy layers are exposed. A thin seam of shale in one of the hard layers contains a few small brachiopods. No other fossils appear. This quarry is evidently in the Portage sandstones but its stratigraphic position in them is not certainly known. It is 5 miles directly south of High Point and 30 miles east and 1 mile north of the cliff at Portageville. The altitude is 1575′ to 1600′ A. T., indicating an elevation of 300 feet to 400 feet or a westerly dip of 10 feet to 13 feet a mile, and a southward dip of 25–30 feet a mile.

Station 7. A small exposure near the foot of the hill on the north side of the road leading from North Cohocton to Wayland, a little east of Dotys Corners. It is about 4 miles west from station 6 and there is not much difference of altitude. A calcareous layer, similar to the one at High Point, but thinner, is composed of Chmeung brachiopods.

Station 8. Quarry 2 miles west of Wayland on the north side of the road to Dansville. Altitude about 1400′ A. T. No fossils have been observed here.


Naples section
High Point S.S.
600
Grimes sandstones 50
312
21
243
30
Genesee shale
Genesee River Section
150 Wiscoy shales
(14) Portage sandstones
182
428 Gardeau flags
25 Flags and shales
209
52 Second black band
130 Cashaqua shales
35 Lower black band
Tide

Station 9. Schubmehl's quarry 1¼ miles northeast of Dansville village. About 60 feet of strata, mainly heavy sandstones are exposed. Some soft shales at the top contain Manticoceras oxy and seem to indicate that the sandstones belong to the upper part of the formation. Altitude 1360′ to 1420′ A. T. This quarry is 18 miles due east of the cliff at Portageville. The only fossils observed were a small Orthis, Cladochonus, crinoid stems and plates, plant remains and F. verticalis. Hydnoceras tuberosum and a few brachiopods occur in a layer of flaggy sandstone that outcrops 1 mile farther north and 325 feet lower.

Station 10. Exposure along the Pittsburg, Shawmut and Northern railroad between 3 and 4 miles south of station 9, and 1 mile north of Rogersville station. About 50 feet of heavy sandstones outcrop in this vicinity. No fossils observed here.

Station 11. In Stony brook and two small lateral ravines about a mile south of the high Stony Brook bridge. Hydnoceras tuberosum occurs in the lower part of the sandstones exposed in the main ravine below the highway bridge.

In the Stony Brook ravine at the high bridge and below to its mouth, about 375 feet of strata are exposed. They show no appreciable difference in lithologic character nor in the contained fossils from the same horizon in the river sections. No brachiopods were observed here but the normal Portage fauna is found in the soft layers.

Station 12. An exposure of about 50 feet of the sandstones ½ mile east of the village of Byersville, in which a thin layer afforded several specimens of Atrypa aspera, a small Orthis, Cladochonus, etc.

Station 13. The outcrops on Quarry hill, 1 mile south of the village of Nunda. About 35 feet of the sandstones are exposed and a shale bed 6 feet thick of the same character as the one occurring a little below the middle of the sandstones at Portageville. A few goniatites and orthoceratites have been found in this shale, and about 25 feet higher a mass of crinoid stems and comminuted shells, in which only a small Chonetes is entire,

was observed. This locality is 5 miles east of the type locality at Portageville, station 14.

West of the Genesee river the normal Portage fauna, with a few additional species embraces all the fossils found up to the horizon of the sandstones.

CONCLUSION

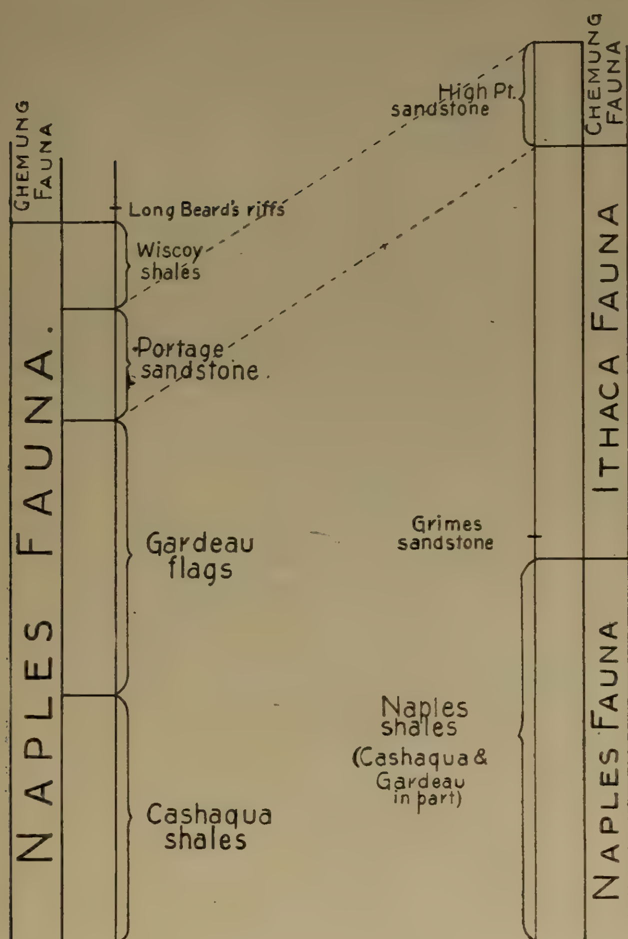
The foregoing statement of facts demonstrates that during the time required for the deposition of 428 feet of upper Gardeau shales and flags, 182 feet of Portage sandstones and 150 feet of overlying Wiscoy shales in the Genesee river section, the normal Portage fauna continued to hold the ground while in the Naples section at the beginning of this period the succeeding fauna had advanced from the east, established itself and remained, driving out the Portage fauna which never returned.

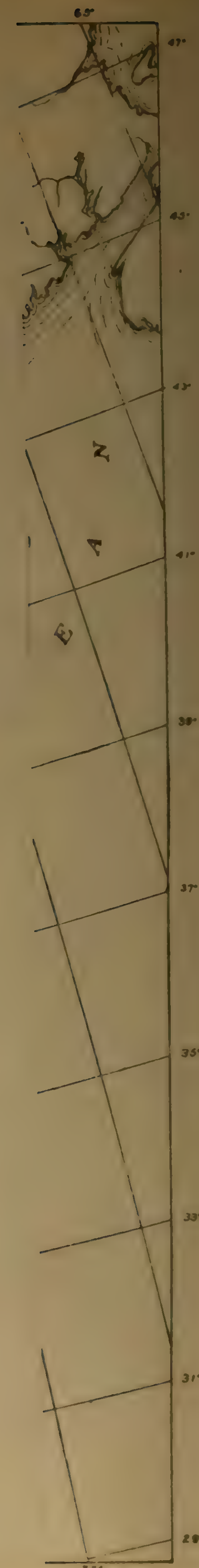
The advance of the later invader toward the west was very slow, and probably broken by periods of recession, for in all that time it covered but 25 of the 30 miles between the two sections.

The upper limit of range of the Portage fauna descends in the strata, very irregularly doubtless, from the top of the Wiscoy shales above Portageville to the bottom of the Grimes sandstones at Naples, a vertical decline in the strata of 760 feet in a distance of 30 miles.

Postscript note by J. M. Clarke. The fauna of the beds in the Naples section, lying between the horizon of last appearance of the Naples fauna, stated by Mr Luther to be just below the base of the Grimes sandstone and the High Point sandstone, can not be properly construed as a Chemung fauna. The list of species cited from this thickness of 600 feet contains species which in a measure occur in Chemung faunas but Spirifer disjunctus is absent below the High Point horizon and none of the molluscan species are foreign to the higher Ithaca fauna pertaining to the Portage province adjacent on the east. The frequent Dictyosponges are more of Chemung habit but these bodies (Hydnoceras, etc.) got their foothold in western New York directly after the disappearance of the Naples fauna, and did not become freely disseminated in the more eastern Chemung deposits. Thus in the correlation of the faunas of the Naples section with those of the Genesee river we may say with approximate accuracy that in the latter the Naples or typical Portage fauna ranges through all beds from the top of the Genesee shales to the top of the Wiscoy shales (Cashaqua, Gardeau, Portage, Wiscoy), a thickness of 1211 feet. In the Naples section this fauna first appears briefly in the Genesee shales, temporarily disappears, reappears with the deposition of the Cashaqua shale and continues through a thickness of 600 feet of sediment. It is then driven out by an invasion from the east of the Ithaca fauna which held the field while the sediments equivalent to the middle and later parts of the Gardeau flags were deposited, and this congeries penetrated part way across the interval but did not reach the Genesee valley. Compared with the eastern development of the fauna in its proper province, it was comparatively few both in species and individuals. After holding the field during the most of the stage of Gardeau deposition it was displaced by the incursion of the Chemung fauna with Spirifer disjunctus, whose earliest presence was contemporaneous with the desposition of the Portage sandstones. This fauna did not reach the Genesee river till, as stated by Mr Luther, the horizon

of Long Beards riffs was reached, 150 feet above the Portage sandstones. So far then as pertains to the aspect of the faunas in these and intervening sections the following diagram indicates the mutual relation.





65°
47°
45°
43°
N
A
41°
E
39°
37°
35°
33°
31°
29°
73°

PALEOZOIC SEAS AND BARRIERS IN EASTERN NORTH AMERICA[1]

BY E. O. ULRICH AND CHARLES SCHUCHERT

The following brief statement of the results of a series of important determinations in Appalachian geology anticipates a fuller discussion of the abundant facts on which they are based and which we hope to publish before the close of another year.

For more than half a century the problems for which it is believed a rational solution is herewith tendered, have engaged the attention of North American geologists. All who have worked on any part of the Appalachian region have observed a great difference in the stratigraphic succession as soon as they entered the area lying just west of the Appalachian protaxis. However careful their investigations, something has remained to be explained, and many ingenious suggestions were offered, without, save obscurely in one instance, attaining the true solution. Stratigraphic continuity was assumed, and the more fragmental character of the sediments along the western flank of the protaxis was believed to indicate little more than proximity to the eastern shore line of the interior sea, while the interruption in the gradual change eastward in the character of the deposits was generally ascribed to overthrust faulting.

But these explanations satisfied neither the stratigrapher nor the paleontologist, and they were accepted only because no better solution of the difficulties was at hand. The fact is, they did not explain and were mere makeshifts, necessitating one assumption after another as detailed mapping progressed.

Apparently the accepted solution did not satisfy that excellent stratigrapher, Sir William Logan, who, in checking the results of his investigations, enjoyed the advantage of close association with so careful and able a paleontologist as E. Billings. With a little more light Logan might have grasped the full significance of the stratigraphic discordance prevailing so constantly

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[1]Published by permission of the director of the U. S. geological survey and of the secretary of the Smithsonian institution.

Plate 9

Map showing Paleozoic barriers in eastern North America.

between the deposits lying to the northwest and southeast of the westernmost of the Appalachian series of overthrust faults in New York and Canada. Indeed, he did recognize, so long ago as 1866, that this overthrust marked in Canada the divisional line between two basins, an eastern and a western.[1] Though we regard the correlations based on this view by Logan, as well as the data from which the idea itself grew, as being at variance with the facts, his suggestion of distinct basins, it seems to us, was far too important to deserve the oblivion to which it has been assigned for all these years.[2]

Though abundant corroborative evidence of the existence of a narrow barrier between the stratigraphically inharmonious areas is afforded by the structural geology of the region in question, it was perhaps scarcely to be expected that the geologists who attacked the problem chiefly or solely from that side would find the true solution. It required detailed paleontologic knowledge, particularly as to assemblages of fossils and their geographic distribution, before the faunal distinctions indicating separate provinces could be appreciated. Had the geologists engaged on southern Appalachian problems received a suggestion from the paleontologists of the striking dissimilarity marking the faunas pertaining to the lithologically equally dissimilar Ordovicic rocks lying respectively on the east and west sides of the Great Valley, it is scarcely conceivable that they would have failed to grasp the leading facts in the case.

Excepting Walcott, who, however, confined his fruitful comparative studies to the Cambric, it appears that no paleontologist having sufficient knowledge of the Ordovicic faunas of the interior, and accustomed to fit his biologic results to stratigraphy, paid much attention to these problems.

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[1] Geol. sur. Newfoundland. Rep't 1864; also reprint in 1881, p. 47.

[2] This theory of Logan's was brought to the attention of the authors but a few weeks ago. Occurring as it does as a note appended to Murray's report, it is not to be wondered that paleontologists remained in ignorance of its existence.

In 1897 and again in 1898, Mr Ulrich made small collections and brief stratigraphic investigations in east Tennessee. The fossils then collected were worked up in leisure moments during the next two years, and, when at last the results were brought together, the suspicion that the Upper Ordovicic strata in the eastern half of the Appalachian valley represent a different geologic province from those along its western edge, had grown to conviction.

The theory, however, was as yet undefined and hazy in its application, requiring much reading and field work to establish the character, position and extent of the barrier that separated the two basins or provinces. The paleontologic evidence in hand indicated a barrier of great length, dividing off from the interior sea a long and narrow body of water in which sediments were laid down containing remains of faunas having relations to those pertaining to east Canadian and European deposits rather than to those of the interior sea.

American, Canadian and European literature likely to bear on the questions involved, made a pile so imposing that without help the publication of the discovery must have been delayed indefinitely, had the work been undertaken by a single person, or it must have been brought out insufficiently supported by facts to demand credence. Mr Schuchert therefore undertook the labor of collating facts from published works, while Mr Ulrich continued the more congenial task of gathering additional evidence in the southern Appalachian field. Between us then, the evidence has been carefully weighed, discussed and correlated, our original theories being constantly modified and brought into accord with accruing facts till, finally, we entertained sufficient confidence in the general truth of the proposition to submit the following summary of results.

The Appalachian series of folds, of which those only that subsequently formed barriers, are discussed in this paper, probably trace their origin to precambric times. Walcott,[1] we believe, clearly demonstrated the existence of a long trough that dur- Lower Cambric trough

[1] U. S. geol. sur. Bul. 81. 1891.

ing Lower Cambric time extended from Alabama northeast to Labrador. It was evidently a synclinal fold—perhaps it would be better to call it a synclinorium—within the southeastern border of a very large Algonkian continent. After the close of the Lower Cambric, this old continent seems to have been subjected to a slight elevation, whose effect, however, made itself manifest principally in the eastern part. Here the Appalachian trough was almost drained of its sea, which appears further to have been confined to the western half of the original trough by the emergence of a fold.

St Croix invasion and birth of Mississippian sea

However, long before the close of the Middle Cambric, as at present defined, a second period of subsidence set in, submergence beginning along the east side of the Rocky mountain protaxis, and spreading northeastward. This submergence, which might be appropriately called the *St Croix invasion*, marks an important event in the development of the present continent, this being nothing less than the birth of the great interior continental sea, to which Walcott[1] has applied the term Mississippian. This sea, sometimes almost oceanic in extent, continued, with some interruptions and more frequent modifications of its outline, through all Paleozoic time. In Mesozoic time it was greatly reduced and restricted practically to the Great Plains region.

St Lawrence channel

With the beginning of the Upper Cambric, which, however, had been preceded by a period of partial reemergence and at least local erosion of the old Lower Cambric land, specially in the southwest, the new sea had transgressed beyond the Adirondacks and soon thereafter probably effected communication with the Atlantic by way of the northern end of the restricted Appalachian trough, or, as this portion might be more appropriately called, the *St Lawrence channel*.[2] This communication with the Mississippian sea either continued through the Upper Cambric and the following Beekmantown age, or it was interrupted and revived again in the latter time. Only once thereafter, i. e. in the Utica age, did it serve the same

[1] Am. ass'n adv. sci. Proc. June 1894. 42: 129-69.

[2] Mr Matthew finds this Dicellocephalus fauna common to America and Europe. See Trans. Royal Soc. Canada, 1893, v. 10, § 4, p. 11.

purpose. A slight transgression in Normans kill time is not taken into account.

Except around certain areas, composed of precambric rocks and supposed to have been islands—notably the Adirondacks of New York and a similar though probably less elevated area lying mainly in Wisconsin—where the deposits were arenaceous, the Upper Cambric sea laid down great beds of limestone. These limestones are chiefly dolomite, and, in this case, indicate 1) remoteness from steep shores of the areas receiving them, 2) considerable depth of water, which may explain the unusual paucity of animal remains contained in them, and 3) chemical precipitation as the main source of the matter composing them.

Upper Cambric limestone

As far as we can learn, it is only in the regions where Upper Cambric deposits are decidedly arenaceous, as in New York, that there is any marked distinction between them and the succeeding strata of the Beekmantown age. Where they are made up of limestones, like the Shenandoah and Knox formations of the Appalachian valley, the Arbuckle limestone of Indian territory, and the Pogonip limestone of Nevada, it appears that sedimentation and probably subsidence continued with little, if any, marked interruption from practically the beginning of the Upper Cambric to the close of the Beekmantown.

Beekmantown limestone

The close of the Beekmantown, however, marks the inauguration of a new arrangement in eastern North America. First, a fold was developed nearly parallel with and presumably a little within the western border of the original Lower Cambric trough; second, another fold, that we have already alluded to as having emerged early in Middle Cambric time, and that was now only accentuated, and reemerged, arose along a line marked in the south by the present western outline of the Ocoee series of rocks and in the north by the Green mountains of Vermont. Though these folds extended apparently without serious interruption from Alabama to and far beyond Quebec, it is doubtful whether the trough bounded by them was ever again entirely submerged subsequent to Beekmantown time. Between them, the western one in the southern and

Era of folding

northern parts, the eastern one in the middle part of the Appalachian valley, they constituted, if we except the Normans kill and Utica transgressions and the Devonic intervals of local submergence, an effective barrier between the interior continental or Mississippian sea and the Atlantic, to the final emergence of the entire Appalachian region.

Barriers named

The western of these two folds, whose geographic position is indicated on the accompanying map, we shall call the *Appalachian valley barrier* or fold, while the eastern is called the *Chilhowee barrier* or fold, when we refer to the middle portion and lower end of the uplift, and the *Green mountains barrier* in speaking of its northern end.

Coincident with the emergence of these folds, the Mississippian sea was restricted to narrower limits, but at present it is not safe to indicate the extent of the land areas then formed. Still it seems certain that, with the exception of the Chazy basin and Levis channel defined in the following paragraphs, all of New York was above sea level.

Appalachian valley trough

The space between the two folds we shall refer to generally as the *Appalachian valley trough* or simply *Valley trough*, and, in order to facilitate reference and geographic accuracy, it is divided into three unequal parts. The southern third, extending from Alabama to southwestern Virginia, we shall refer to as the *Lenoir basin*, the middle third, extending on to New Jersey, forms part of the subsequent *Cumberland basin*, and the northern third, extending as far as Newfoundland, will be called the *Levis channel*. Parallel with, but shorter than the Levis channel, and immediately northwest of the Appalachian valley barrier, lies the *Chazy basin*, with its typical Chazy deposits and fauna.

As will be seen later, these divisions are distinct though indefinitely bounded basins, of which the central one was commonly occupied by the Mississippian sea, while the terminal basins were generally taken up by Atlantic waters.

Immediately following the emergence of the folds and the broader land area just mentioned, there began a period of sub-

sidence, whose earliest effects, so far as marine deposition is concerned, are seen in the Chazy limestone of the northeast and the lower Stones river formations of Tennessee and Kentucky. In the latter regions the subsidence continued, without serious interruption, to the close of the Black river, when elevation, resulting in the first emergence and subsequent erosion of the Cincinnati and Nashville domes or *parma* of Suess, took place. In the meantime, the Mississippian sea, which seems to have entered from the south, was steadily advancing northeastward, reaching the Mohawk and St Lawrence valleys, as we shall have occasion to explain more fully, just before the close of the Stones river age. Stones river invasion

With the earlier part of this subsidence, the Atlantic invaded the continent westward by means of the two subparallel and closely approximated channels that we have called the Chazy bay and the Levis channel. The former extended along the northwestern side of the Quebec barrier, which separated the two channels, up the St Lawrence to the northeast angle of the Adirondack mass, where it divided, one arm entering the Ottawa basin, the other passing on up the Champlain valley to or about Westhaven. The typical Chazy formation, which represents the deposits of this bay, bears evidence in its members of having encroached southward and westward in the arms, the latest beds, except where, apparently, they were removed before being covered by the next formation, extending farthest south and west. Chazy invasion and bay

The Levis channel, which occupied the narrow trough between the Quebec and Green mountains barriers, extended from Newfoundland southwestward as far at least as Rensselaer county, N. Y., where Ruedemann has found the typical Levis fauna. Its deposits consist almost wholly of shales, with occasional rather local thin bands of impure limestone and accumulations of conglomerates, as at Levis opposite Quebec city. The faunas, which in their general aspect are decidedly European, consist mainly of graptolites, that of the Levis formation being particularly characterized by several species of Phyllograptus. The respec- Levis channel

tive faunas and the lithologic character of the deposits in the twin channels are so different that we can not doubt the thorough effectiveness of the Quebec barrier during the whole of Chazy time.

Lower Dicellograptus fauna

At the close of the Chazy the northwest channel, and perhaps the Levis channel as well, was drained. This emergence continued in the Chazy basin till Black river time, but, if the drainage occurred simultaneously in both channels, appears to have been of briefer duration in the Levis channel. On the other hand, it seems very likely that the Chazy bay was emptied sometime in advance of the Levis channel, allowing deposition in the latter of beds holding the lower Dicellograptus and Agnostus, Ampyx, Aeglina and Paterula fauna, which is common to Europe and the Levis channel. The earlier emergence of the Chazy channel is rendered very plausible if we assume a period of compression at the close of the Chazy, causing the strata in the western channel to be pushed up on the sloping Adirondack and Laurentian masses beneath them, and high enough to empty the western channel but not the Levis channel. The same assumption would explain the development of the supposed barrier, referred to a page or two farther on, across the mouth of the Ottawa arm of the Chazy bay, which, if it ever existed, must have arisen about this time.

The deposits and fauna of the supposed lower Dicellograptus zone in the Levis channel are now known chiefly, if not solely, from limestone pebbles and boulders preserved in the conglomeratic horizon at the base of the Normans kill shale, the bed itself possibly being now entirely covered by overthrust Cambric rocks. The fauna contained in these pebbles, as worked out by Ruedemann,[1] contains species indicating some communication with the Mississippian sea in the vicinity of Albany N. Y.; or it may be that the sea of the Normans kill shale, which transgressed farther westward, also washed surfaces laid down by Black river and early Trenton seas.

Normans kill shale

The Normans kill shale, which, as we have just said, transgressed a little farther west, also extended farther southward

[1] N. Y. state mus. Bul. 42. 1901; Bul. 49, 1902. p. 89-94.

in the gradually submerging Appalachian valley trough into New Jersey[1] and probably across the Delaware into Pennsylvania, where, according to Weller, it rests on Lower Trenton or Black river limestone. If this succession is normal, then we have a good indication of the age of the Chazy, and again of the later strata containing the distinctively European fauna characterized by Paterula, Christiania, Agnostus, Ampyx and Aeglina. The latter must be older than the Black river and younger than lower Stones river, the latter of which we consider about equivalent in time to the Chazy and Levis. Following the same line of reasoning, we see that the Chazy of the Champlain-Quebec valley and the Ottawa basin was succeeded by an interval of elevation and probable erosion preceding the Black river invasion. Again we conclude, the upper limit being fixed by evidence touched on in a succeeding paragraph, that the Normans kill shale is about Middle Trenton, as demonstrated by Ruedemann, or a little later in age.

While the Chazy and the greater part of the Stones river deposits were being laid down elsewhere, nearly all of the middle Appalachian area, together with New York and much of Canada north of the St Lawrence, constituted a great and continuous land area, and it was only with the advent of the Black river and the underlying Lowville limestone, which is equivalent to the extreme top of the Stones river, that the Mississippian sea at last spread over a considerable part of this territory. Judging from the uniform age of the basal member of the Mohawkian in New York and Canada, it seems almost certain that the Black river sea accomplished the submergence of the troughs surrounding the Adirondacks and lying south of the Laurentian nucleus, or Canadian *shield* of Suess, almost simultaneously. It is therefore eminently proper to speak of this stage of the subsidence as the Black river invasion.

Black river invasion

The Trenton sea seems to have maintained very nearly the same outline here as the Black river, and like that sea, at first, and then again near the close of its age, transgressed the Quebec

[1] Weller. Geol. sur. N. J. An. rep't, 1900. p. 5; and Kümmel, p. 53.

barrier so as to occupy the northern third of the valley trough from the mouth of the Mohawk to Montreal. Beyond the latter point to Quebec both the Black river and Trenton deposits were probably confined to the area covered by the former Chazy bay.

Trenton transgressions eastward

Between the two Trenton transgressions the Normans kill shale intervened, its western edge overlapping the first and being in turn covered by the second. The latter eastward transgression of the Trenton is indicated chiefly by the fauna of the calcareous shale overlying the Normans kill. A careful study of Mr Ruedemann's list of this fauna reveals nothing incompatible with a late Trenton correlation.

Ottawa bay

Immediately succeeding the Chazy, there is reason to believe, a fold was developed across the mouth of the Ottawa bay that has since been worn down to Upper Cambric rocks. This fold must have been higher than the land formerly bounding the western end of the bay and separated a new Ottawa bay now coming in from the west, probably by way of Lake Nipissing, from the narrow Champlain-Quebec basin. This separation is indicated by both structural and paleontologic evidence.

Utica invasion

At the close of the Trenton the Cincinnati axis or *parma* experienced one of its periodic uplifts, and with it much of the area west of it was raised above sea level. The region to the east of it and north of the Ohio river, on the contrary, seems to have been slightly depressed. Apparently the subsidence was greatest in the Mohawk valley and in the Levis basin of the Appalachian valley trough, and sufficient to render the Quebec barrier wholly ineffective here. The northeast communication with the Atlantic, now considerably enlarged by the subsidence, brought in with the decided southwest current, ingeniously demonstrated by Ruedemann,[1] a fauna wholly new to the Mississippian sea, having, as has been already asserted by Matthew and more recently by Ruedemann,[2] strong European affinities.

[1] Am. geol. 1897. 19:367-91; 1898. 21:75-81.
[2] N. Y. state mus. Bul. 42. 1901. p. 562.

This communication with the Atlantic through the St Lawrence continuation of the Appalachian valley trough was, however, not of long duration, nor did the foreign element of the Utica fauna impress itself to any appreciable extent in the development of succeeding faunas of the Mississippian sea. A slight elevation and it ceased, the preceding Trenton life condition being reestablished.

The first deposits laid down in the Mississippian sea, following the return to the Trenton arrangement of parts, are the Frankfort shales, which we regard as equivalent to the Middle and Upper Utica of Nickles's Cincinnati section,[1] the typical Utica barely reaching that point, though something like 300 feet thick in northwestern Ohio.

Frankfort shale

The Lorraine sea extended eastward into the Mohawk valley of New York only as far as Rome, being there limited by a low north and south fold, that later on becomes conspicuous again as the western limit of the Helderbergian invasion. The Lorraine of the Hudson river valley has been shown by Ruedemann to be the equivalent of the Frankfort shales with a fauna transitional from the Utica to the higher Lorraine.

In the north the effect of the lateral compression to which the Appalachian region was periodically subjected during the Paleozoic is particularly marked in the area lying just east of the Adirondack mountains. The Ordovician sediments here were piled in distorted and broken masses and largely covered by overthrust Cambric deposits. As might be expected, the eastern one of the two (Chazy and Levis) channels that intervened between the Adirondacks and the Green mountains has been almost obliterated, so that it is now very difficult to trace out the relations of the remnants of its deposits, which crop out only here and there from beneath the overthrust masses of older rocks. Still, with careful stratigraphic and paleontologic comparison, we believe the task is not hopeless. Ruedemann's important results about Albany, Ami's recent work at Quebec, and Dale's careful areal work, look, to say the least, encouraging and augur even greater results in the near future.

Maximum of compression east of Adirondacks

[1] Cincinnati soc. nat. hist. Jour. 1902. 20:49-100.

Having described the Ordovicic conditions that prevailed in New York, and the bearing of the Appalachian barriers in their development, we turn to a briefer discussion of the conditions obtaining at the same time in the regions containing the middle and southern thirds of the Valley trough.

While the Chazy and succeeding Ordovicic deposits were being laid down in the north in waters having direct communication with the north Atlantic, another series of rocks was in course of deposition in a bay separated from the Mississippian sea by the

Rome barrier and Lenoir basin

Rome barrier, which is the sharply defined southern extension of the Appalachian valley fold. This bay may take the name of *Lenoir*. It communicated with the Atlantic at its southern end and extended northeastward between the Rome and Chilhowee barriers from middle-eastern Alabama to southwestern Virginia.

Athens and Knoxville troughs

The Lenoir bay occupied a synclinorium containing several disconnected longitudinal folds high enough to affect the direction of currents and consequently the character of the sediments and, in a smaller degree, faunal distribution. In a general way the deposits may be divided into an eastern (*Athens trough*) and a western series (*Knoxville trough*), the members of which, on account of differential warping and subsidence, and lateral conjunction, overlap or grade into each other along the shifting median line. On the eastern side we have the Athens shale and sandstone, which are supposed to correspond with the Lenoir limestone of Safford (in part the same as the Chickamauga limestone of Hayes, Campbell and Keith), and its great lenses of Holston marble

Correlation of Ordovicic deposits in Lenoir basin

occupying the western half. Compared with the sediments in the northern Appalachian troughs (Chazy basin and Levis channel), they probably fill the interval there occupied by the Chazy, Levis and Normans kill shale. The Tellico sandstone and the Moccasin limestone follow, the former in the eastern half, the latter in the western, while the Sevier shale spreads over both sides. The last formation probably is equivalent in time to late Trenton and, possibly, Utica.

These Lenoir bay deposits contain faunas wholly distinct from those pertaining to the true Chickamauga limestone series, which

was deposited at the same time and in great volume along the western side of the Great Valley of east Tennessee by the Mississippian sea, from which the bay was separated by the narrow Rome barrier. The Chickamauga limestone embraces in this region unmistakable representatives of every important member of the sections of middle Tennessee and central Kentucky, ranging from the base of the Stones river to lower Lorraine; and the Stones river divisions are particularly characteristic. Chickamauga limestone

Elevation of the Lenoir basin now (presumably at close of Trenton) took place, bringing in a very different arrangement. The elevation was greatest at the southern end, thus cutting off all communication with the Atlantic. At the same time the middle third of the Valley trough sank, allowing the waters of the Mississippian sea, which, at least from Black river time on, occupied the middle third, to invade southwardly into the former confines of the Lenoir bay. The result of this revolution and invasion is the Bays and Clinch sandstones, and the lower, nonferruginous, shale division of the Rockwood formation, all of which, as is indicated by fossils collected from the last by M. R. Campbell, of the U. S. geological survey, are of Cincinnatian (perhaps Lorraine) age. Continued elevation of the southern end of the Valley trough is indicated by the fact that of the three formations mentioned the first extends farthest south, the second not so far, and the third again falling short of the Clinch. Bays and Clinch invasion

Before the close of the Ordovicic both the Lenoir bay and the Cumberland basin had been raised above sea level. This emergence took place about the beginning of the Richmond age, during which the Mississippian sea was restricted to the Ohio valley and west and south of the Cincinnati line of uplift. Prior to this time, or at the beginning of the Lorraine, which probably corresponds very nearly to the time of the Bays and Clinch invasion described in the preceding paragraph, there was another emergence that reduced the Frankfort phase of the Mississippian sea by excluding its waters from the valley of the upper Mississippi and from the various basins lying east and south of Rome N. Y. We see, then, that both of these emergences were ac- Richmond emergence

companied by a submergence, the older taking place, as we have described, in the region of the middle third of the Appalachian valley, the later one in the west, where the preceding Lorraine land was again submerged.

Richmond submergence

The Richmond submergence is of great importance in the geologic history of the North American continent, fossil evidence bearing on the point indicating open communication of the entire Mississippian sea, then existing, with Anticosti and northern Europe. But as this communication was certainly not by way of the St Lawrence-Champlain valley, and the problem therefore is not intimately connected with the subjects of this paper, its discussion is deferred.

Toward the close of Ordovicic time the lands and seas, as evidenced by the two Lorraine and Richmond emergences and submergences described, had become unstable. Now followed one of the greatest earth pulsations in North American Paleozoic history. The disturbance referred to, Dana[1] says gave birth to the Taconic mountains; and we will therefore call it the Taconic revolution. That this movement was one not only of elevation but also of considerable folding of the earth's crust, is shown in the fact that the Helderbergian deposits overlie unconformably the Ordovicic strata, as at Becraft mountain, New York. That its effects were extensive is indicated by Dana's remark, "The Taconic . . . series of upturnings appear . . . to extend all the way from the St Lawrence valley to New York city."

Taconic revolution

This revolution affected all North America, and there was land perhaps throughout from Richmond to Oneida time. The length of this land interval we can not perhaps now ascertain satisfactorily, because there are no Mississippi sea deposits by which its duration may be measured. In Minnesota, and more particularly in Manitoba, there are late Ordovicic deposits with prophetic Siluric genera and species which apparently indicate that the land interval was not of long duration. "After a mountain birth," says Dana,[2] "there has commonly succeeded a time

[1] Manual of geology. Ed. 4. 1896. p. 386 and 531.
[2] Manual of geology. Ed. 4. 1896. p. 386.

of relaxed lateral pressure; and then occurred adjustments, largely by gravitation." Certainly this is true in this instance, for after the subsidence had commenced it continued nearly through all Siluric times.

The Oswegan subsidence or invasion, as it may be called, began with the Oneida and continued with little interruption to the close of the Salina age. In New York these deposits thin out eastward, and one after the other formation overlaps the older, so that in the region south of the Mohawk river the Eurypterus bearing Waterlime, which is the uppermost division of the Salina, appears not to have reached the eastern side of the Helderberg mountains. The Clinton, Niagara and Salina also pinch out one after another west of the Helderberg mountains. To the south, the equivalent deposits transgress even less toward the Appalachian protaxis, the eastern line in middle Pennsylvania swinging westward to the vicinity of Altoona. From this point southwestward the line, judging from the data available, seems to have run about parallel with the general trend of the Appalachian folds into West Virginia, and it probably swung eastward again toward the Appalachian valley fold before passing through that state. This westwardly bent line has great significance, because it corresponds with the course of a barrier defining the western limit of another basin, the *Cumberland basin*, that was occupied by an Appalachian Mediterranean, with a fauna very different from that of the contemporaneous Mississippian sea. We mention this a little out of the regular order of our description, so that the reader may understand why the Siluric deposits east of the Helderbergian barrier just located are not regarded as continuations of the sediments of the Mississippian sea.

Oswegan invasion

Cumberland basin and Helderbergian basin

In the southeastern portion of the Mississippian sea the Oswegan invasion was limited by the Rome barrier, and began with a shale instead of conglomerate and sandstone. This character of deposits continued with occasional interruptions of thin, ferruginous, fossil limestones, and locally heavier beds of sandstone, to the close of the Clinton. There are no deposits of

Rome barrier in Siluric

Niagara, nor of any later Siluric age in east Tennessee, unless the Niagara is represented in the extreme upper part of the Rockwood formation, the shales and sandstones of this formation being as a rule succeeded in this area by the Devonic Chattanooga shale. The existence of a land surface, extending westward from the protaxis across east Tennessee to the western slope of the middle Tennessee dome, therefore is assumed as filling the interval between the close of the Clinton or early Niagara to the middle Devonic. The Cincinnati dome also was above sea level at the same time, and connected with the east Tennessee land in such a manner that a broad bay was left between the two domes. Neither of the latter was ever covered entirely by Siluric strata, these being laid down only on their gently sloping shores and in embayments produced by slight warping of their surfaces. The succession of the deposits in these embayments shows very clearly that the emergence at the close of the Clinton was soon checked, and that gentle subsidence prevailed in later Niagara time.

Siluric land in Tennessee and Kentucky

Throughout Cayugan time, on the contrary, the Mississippian sea was growing shallower, the floor of the sea having risen almost gradually till, at the close of the Rondout, the whole interior of the continent west of the Helderbergian barrier had become land. This important emergence, for which we propose the name *Cayugan*, continued from Waterlime to Onondaga time, when the Mississippian sea again came in from the southwest, spreading far and wide in the United States. In its eastward progression this invasion (Onondaga) did not reach middle and east Tennessee till near the close of the Black shale, which is commonly correlated with the Genesee. The southern Black or Chattanooga shale, however, may really represent late Devonic time only, since in complete sections the shale in question seems to pass very gradually into undoubted basal Mississippian (Carbonic) shales.

Cayugan emergence

Helderbergian invasion

While both the Oswegan subsidence and the following Cayugan emergence were affecting the area to the west of the Helder-

bergian barrier, mentioned above, the region east of the barrier, comprising the Cumberland basin, was steadily going down, the subsidence allowing an invasion of an Atlantic sea and fauna to which the name *Helderbergian invasion* may be very appropriately given.

This invasion brought in a European fauna by way of the *Hercynian chain* believed to have connected North America with central Europe (Bohemia, Hartz, etc.). We think this line is in the main correctly drawn by Bertrand,[1] though we would draw it on the American side more to the north—nearer to his *Caledonian chain*—so as to bring the Helderbergian and Oriskanian deposits of Gaspé, Quebec, into more direct connection with those of the Appalachian Mediterranean.

Appalachian Mediterranean, or Cumberland basin

This invasion of the United States began early in Siluric time, occupying then and to close of Oriskany time the growing Cumberland basin lying, as described above, east of the Helderbergian barrier. The connection between this Appalachian Mediterranean and the Atlantic, which will be further discussed in treating of the Marcellus invasion and the Skunnemunk trough, is supposed to have been about in the region of Chesapeake bay.

To the north and south of Cumberland Md., there is a great series of rocks, beginning with shales and passing upward into limestone, and characterized by a succession of prolific faunas.[2] Very few of the species of these faunas are identical with species of the Mississippian sea of Siluric time. The earliest fauna recalls the Clinton, and passes into one which may be compared with the Niagaran, and then a great series of limestones, abounding in minute Ostracoda, which may be compared with the Salina on account of the prevalence here also of larger Ostracoda of the genus Leperditia. Then comes in without

[1] Soc. geol. de France. Bul. Ser. 3. 1887. 15:442.

[2] This series of rocks rests on the Tuscarora and Juniata formations. These coarse deposits have afforded very little satisfactory fossil evidence, so that we do not yet know whether they belong to the Mississippian sea or the Appalachian Mediterranean.

break the Decker Ferry fauna listed by Weller,[1] the Manlius, with a magnificent cystid fauna, among which is Camarocrinus in great abundance, followed by the typical Helderbergian and Oriskanian. The respective faunas of these formations may be gathered in the vicinity of Cumberland and southward for a hundred miles or more into the Virginias. Continuing in this direction, overlap causes the lower formations to wedge out one after another till, finally, only a little of the Helderbergian and Oriskanian series is represented in the Sneedville or Handcock limestone of southwestern Virginia and northeastern Tennessee. Northward from Cumberland, through Pennsylvania and New Jersey into New York, the lower formations pinch out in the same manner as in the south, so that in the Kittatinny valley of New Jersey it is practically the Decker Ferry formation only that rests on the "red and white Medina" or Shawangunk. From here north, however, the Decker Ferry, Manlius and Helderberg formations continue in full force to near the Mohawk river, presenting thus a condition differing widely from that obtaining in the southern end of the basin. It is in this northern area that one finds the extensive and readily accessible Helderbergian deposits that furnished the fauna so well described and beautifully illustrated by Hall. For this reason, and because the subsidence appears to have been continuous, we have chosen the name *Helderbergian* for the invasion. In the other cases of movements named by us, we have taken the name

[1] Geol. sur. of New Jersey for 1899. 1900. p. 7-21. Some of these identifications are admittedly provisional and require verification, Mr Weller having followed Hall's correlation of the Coralline limestone as the eastern representative of the western Niagara, an obvious error now that we know that the Coralline limestone lies just below the Rondout, at Rondout N. Y. However, the typical Rondout should not be confounded with the Waterlime of Buffalo N. Y. The Rondout formation is but the base of the Manlius, and the former is completely transitional downward into the Coralline limestone. The Helderbergian invasion in New York begins with the Coralline, while the Cayugan emergence closes with the so called "Clinton" of the Schoharie section, which we consider the overlapping eastern edge of the Salina deposits, and certainly not equivalent to the true Clinton.

from that of the formation introducing the movement, but in this case the formation that might claim that distinction has not been named nor has its fauna been described.

Helderbergian of Montreal, Gaspé and Dalhousie

The small Helderbergian outlier near Montreal[1] probably belongs with the Gaspé series, since there is no clear evidence that the Albany county, N. Y., area ever connected with Montreal by way of the Champlain valley, as was supposed by Logan and Dana[2] to be the case. About Gaspé there is a grand development of Helderbergian and Oriskanian, whose faunas are closely related to those of their equivalents in New York; and another area occurs near Dalhousie N. B., with a fauna peculiar to it. Concerning these two areas, the latter appears to belong to a subprovince distinct from that of the Appalachian Mediterranean.

The Helderbergian invasion of the southern Mississippi valley began after the Cayugan emergence, since its first deposit seems to be of Coeymans age. Part of the underlying Meniscus or Clifton limestone of Safford may also belong to this invasion. It came in from the south and spread north along the western side of the Cincinnati arch through Tennessee into southern Illinois and Missouri. The invasion continued throughout Helderbergian time and ceased with the Camden chert of early Oriskany age. Another area lies in Indian Territory, and the faunas of all the southern Helderbergian and Oriskanian deposits are of the Appalachian facies.

No Helderbergian deposits are reported from the Rocky mountain region, but we have good reasons for stating that equivalent deposits occur in the Devonic of the White Pine and Eureka districts of Nevada as defined by Walcott and Hague, holding a rather peculiar, though on the whole recognizably Helderbergian fauna.

Oriskanian emergence of Appalachian Mediterranean

The Oriskany formation in the Appalachian Mediterranean, or Cumberland basin is in full force only in the region to the north and south of Cumberland Md. In southern Pennsylvania,

[1] Schuchert. Am. geol. 1901. 27:245-53.

[2] Manual of geol. Ed. 4. 1896. p. 558.

Maryland, and thence south along Appalachia, the Oriskanian emergence continued to close of Onondaga time; and, as we have already described in considering the Cayugan emergence, affected not only the Appalachian Mediterranean but the southeastern area of the Mississippian sea as well. In middle Virginia emergence began early in Oriskany time, since no true or Upper Oriskany is known in southern Virginia or Tennessee. To the north of Cumberland Md. the Oriskany is unequally developed, but in eastern New York it appears to be the higher portion only that is present. With Lower Oriskany only in the southern extremity, and Upper Oriskany only in the northern end, the movements evidently were directly opposite at the two extremities of the Cumberland basin during Oriskanian time. The land conditions that succeeded the Oriskany in the Cumberland basin continued till about Marcellus or Middle Devonic time, when the later Devonic deposits of the Skunnemunk invasion were laid down.

Oriskanian invasion of the Mississippian sea

Immediately succeeding the Oriskany emergence of the Cumberland basin, there still remained in southern New York a depression through which the Atlantic fauna of the Oriskany invaded the Mississippian province. This invasion, coming in from the southeast (the Esopus, which is only a phase of the Oriskany, is 700 feet thick, according to Ries,[1] in Orange county, N. Y.) spread northward, over the Oriskany, and, after crossing the Helderbergian barrier at Rome, continued on westward by way of Buffalo, where remnants of it are seen in the cement quarries.[2] Finally, the last of this deposit is seen near Cayuga Ont.

Onondaga invasion

The Oriskanian invasion attained the last locality about the same time that the Onondaga invasion, coming in from the southwest, arrived there, the result being that the Onondaga and late Oriskany faunas, originally very dissimilar in character, became one, making together what is now known as the eastern Onondaga fauna.

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[1] Ries. N. Y. state geol. 15th an. rep't 1897. 1898. 1:402.

[2] Grabau. Geol. soc. Am. Bul. 1900. 11:355-62.

The blending of these two different faunas can be seen to best advantage in the townships of Oneida and North Cayuga, Ont., where there is a sandstone filled with late Oriskany fossils. The sandstone rapidly passes into a sandy limestone and then into the typical Onondaga limestone. If it were not for the structural dissimilarity of the beds, these two faunas could not be separated, since it has been shown that out of 71 species found here, not less than 42 pass up from the lower horizon into the Onondaga;[1] yet the lower horizon has such characteristic Oriskany species as Spirifer arenosus, Chonostrophia complanata, Rhipidomella musculosa, Stropheodonta magniventra, S. vascularia, Eatonia peculiaris, etc. On account of the marked Onondaga aspect of its fauna, it is unwise to call this Ontario deposit Oriskany any longer, and we here propose to call it the *Decewville* formation, taking the name from the village nearest to its exposures. We include in the formation the coarse basal sandstone and the thin bedded sandy limestones up to where the typical Onondaga limestone appears.

A careful analysis of the Schoharie grit fauna of eastern New York, and of the Pendleton sandstone of Indiana[2] will probably also show a blending of the invading Oriskany and Onondaga faunas, though probably less marked than it is at Decewville Ont.

A further instance, or rather, a survival of the blending of the Oriskany and Onondaga faunas, is shown at Clarence Hollow N. Y., where Spirifer arenosus (described as S. unica Hall) occurs in the Onondaga limestone.

By the time the Onondaga invasion had become established in the Mississippian province, the Cumberland basin, including its last remnant, the Oriskanian channel already discussed, had been wholly emerged, thus cutting off all communication with the Atlantic in this region. This severance, however, was of

[1] Schuchert. N. Y. state geol. 8th an. rep't. 1889. p. 51-54. Also Geol. soc. Am. Bul. 1900. 11:323-26.

[2] Siebenthal. Ind. dep't geol. and nat. res. 25th an. rep't. 1901. p. 347.

short duration, lasting only, as we shall endeavor to show, till early Hamilton (Marcellus) time, when the subsidence, which in the meantime affected the greater part of the southeastern fourth of the continent, reopened the Oriskanian channel and, extending it eastward, allowed invasion from that direction. This Marcellus invasion produced considerable intermingling of the Atlantic and Mississippian faunas, specially in those laid down in the modified but resubmerged Cumberland basin.

Skunnemunk trough and formations in it

In the Skunnemunk and Green Pond mountain region, the former in southeastern New York, the latter in New Jersey, there is a series of coarse deposits apparently occupying a syncline. The oldest formation above the presiluric deposits is the Green Pond conglomerate, supposed to be of the age of the Shawangunk farther north. From this on, deposition appears to have been continuous to the close of the Helderbergian, when this area, in common with the Cumberland basin to the west of it, was affected by the elevation of the eastern side of the continent. Resubmergence began here with the Monroe shales,[1] which rest on Oriskanian strata, and continued through the Bellvale flags into the Skunnemunk conglomerate, which Darton suggests "may represent the Oneonta" or "the formation may be the equivalent of the coarse beds of the Chemung." Fossils from the Monroe shales sent by Darton to Hall were pronounced by the latter to be of "typical lower Hamilton (group) species."[2] The Bellvale flags contain Tropidoleptus carinatus, Spirifer mucronatus, and, more commonly, land plants, recalling those described by Dawson from the Gaspé sandstones. According to Ries the total thickness of the Devonic deposits (succeeding the Esopus or Oriskany) in the Skunnemunk and Bellvale mountains of New York, is about 1500 feet; while Darton gives a thickness of 5400 feet for the equivalent series in the Green Pond area of New Jersey. This difference in volume is cited in support of our opinion that the great-

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[1] Darton. Geol. soc. Am. 1894. v. 5; Ries. N. Y. state geol. 15th an. rep't 1897. 1898. 1:403-4, 410-24.

[2] Darton, op. cit, p. 375.

est depression of the Skunnemunk trough and the Cumberland basin was to the south of New Jersey, and there permitted the Atlantic during the Marcellus to spread its fauna across the Chilhowee barrier into the Mississippian sea. Marcellus invasion

These deposits were laid down in waters occupying a trough lying east of the Appalachian valley trough, and hold, as do also the equivalent sediments of the Cumberland basin, faunas having different aspects from those of the Devonic west of the Cincinnati axis. The communication between these basins or troughs and the Atlantic was, we believe, effected by channels corresponding in position to the present Chesapeake and Delaware bays. We believe further that it was through these channels that the Skunnemunk trough and the eastern Mississippian sea, the latter covering Virginia, Maryland, Pennsylvania and New York at the time, received its Marcellus accessions. These migrants are now found mixed together with the indigenous early Hamilton faunas as far west as western Ontario (Thedford). Some of these European accessions are Strophalosia, Liorhynchus, Tropidoleptus, Tentaculites, Styliolina, Actinopteria, Pterochaenia, Bactrites and Tornoceras.[1]

Our derivation of this fauna from Europe by way of the Atlantic goes further than Dr Clarke's views. He regards it "as an invader from the southeast along the inner or Appalachian face of the interior sea."[2] The Marcellus is well developed about Cumberland Md., and south to about central Virginia, where this formation pinches out. We therefore conclude that the invasion from the Atlantic was somewhere in the Chesapeake bay region. The bulk of the Marcellus fauna is however indigenous to the eastern Mississippian sea and is a development out of the Onondaga.

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[1] We should not have been able to make these statements, had we not the excellent work of Dr Clarke on the Marcellus faunas. These papers are the following: N. Y. state geol. 4th an. rep't 1884. 1885. p. 11; N. Y. state mus. 42d an. rep't. 1889. p. 406-97; N. Y. state mus. Bul. 49. 1902. p. 115-38 and Miss Wood's paper following on p. 139-81.

[2] Ib. p. 115.

The Hamilton deposits of Michigan, Wisconsin and Iowa, however, belong to a distinct subprovince, and received their main accessions from another direction.

Portage invasion

We believe another Atlantic invasion of the eastern Mississippian sea occurred during early Portage time, introducing a good part of the very characteristic Naples fauna, as Manticoceras, Gephyroceras, Beloceras, Sandbergeroceras and Cyrtoclymenia. The goniatite fauna of this formation, according to Dr Clarke's[1] work, consists of no less than eight genera and 25 species, and yet in no other American area holding beds of similar age, occurs more than one species of goniatite. (Manticoceras intumescens, the widely dispersed European species, is also found in Iowa and on Hay river, latitude 60° north.) This fauna is closely related to that "of Martenberg in Westphalia."[2] How long this Atlantic invasion continued we do not pretend to state, but it is certain that the indigenous Upper Devonic faunas of New York not only received the above supposed Atlantic migrants, but also some from Iowa, as in the High Point (N. Y.) faunula. The Mackenzie basin Upper Devonic fauna, characterized by Stringocephalus burtini, is of a distinct subprovince; but the geographic derivation of that fauna we do not yet know. We are however satisfied these Mackenzie Devonic deposits had no direct connection with those of Iowa.

Carbonic[3]

There appears to be a complete series of Devonic deposits, with the possible exception of the Onondaga, in the middle third of the Appalachian Valley trough, but early Mississippian seems to be wanting in this portion. In the southern end, the early Carbonic, represented just west of the Rome barrier by the Fort Payne chert, also was partially excluded; but the St Louis, and possibly Chester, are represented in the trough at several points. The Fort Payne chert is represented within the extreme

[1] Am. geol. 1891. p. 86-105; N. Y. state geol. 15th an. rep't. 1898. p. 31-81; also ib. 16th rep't, extract. 1898. p. 31-143.

[2] Clarke. p. 136.

[3] For this section Mr Ulrich alone is responsible.

southern end of the trough by several small patches, in Polk county, Ga., some 20 miles north of Tallapoosa. These patches evidently are remnants of a tongue of this formation that extended northeastward to this point and occupied a syncline along the eastern side of the Valley trough, this particular syncline being now almost entirely covered by overthrust Ocoee slates and conglomerates. Its connection with the main body of the Fort Payne deposit is at present conjectural.

The shore line of the main body of the early Mississippian sea followed the western side of the Rome barrier rather closely to probably some point in Virginia, where it broke through the line and sent tongues southward in secondary depressions within the Appalachian valley synclinorium. These secondary depressions may in a general way be said to have been occupied at an earlier period by the sea which laid down the Devonic Black shale, and which entered the trough probably through the same opening. Subsidence of the middle third of the Valley trough continued in second half of Mississippian time, resulting in greater expanse in the Appalachian region of Newman limestone and Pennington shale, which, together, represent the St Louis and Chester deposits of the Mississippi valley. These formations, however, do not extend over much of the basinlike area occupied by the early Mississippian-Waverly sea in Ohio, northeast Kentucky and the adjoining corner of West Virginia, the Waverly basin, lying between the middle Tennessee-Cincinnati line of uplift and the Appalachian-Chilhowee barrier, having been in St Louis and Chester times, much reduced in its northern and northwestern extent.

The Carbonic strata of Michigan were deposited in a basin formed by the bifurcation of the Cincinnati axis, and probably had only a slender or possibly no direct connection with the Waverly basin to the southeast of it. At any rate, the evidence in hand indicates that, if the connection existed at all, it was severed about the beginning of the St Louis age.

The coal measures east of the Mississippi river were inaugurated by a slight subsidence beginning perhaps with an ice age.

During the period, the area was subject to frequent oscillations of level, marine conditions prevailing during the subsidence, and land and brackish water when elevations occurred. The area of subsidence, however, did not include any portion of the Appalachian trough, but was terminated along its eastern side by a decided elevation of the old Appalachian valley fold, and a sufficient elevation of the entire Valley trough to bring it permanently above sea level.

West of the Valley fold, and between it and the northeastward continuation of the Sequatchie anticline already mentioned, there was a shallow basin that, at least in Pennsylvania, was occupied by a bay. This bay was in existence during the whole or a portion of the time consumed by the deposition of the Pottsville series, and, as it became filled up with sediment and subsidence continued, gradually merged into the main sea.

UMississippian, Appalachian valley, and

ʼn the same line indicate supposed equivalence in age only.

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ROVINCE M	Skunnemunk basin	GENERALIZED TIME SCALE FOR EASTERN NORTH AMERICA
Ca	Land	Carbonic
Ch	Skunnemunk	Chemung
Po		Portage
Ge	Bellvale	Genesee
Tu		Tully
Ha	Monroe	Hamilton
Ma		Marcellus
On		Onondaga
	Land	
Scl		Schoharie
De	Esopus	Decewville and Esopus
Up	Oriskanian	Upper Oriskany
		Lower Oriskany
		Kingston
	Helderbergian	*Becraft*
		New Scotland
		Coeymans
Ma		*Manlius*
La	? Land	*Decker Ferry*
Rod.		Rondout
Sal		Salina
Gu		Guelph
Loat	*Longwood*	Lockport
Ro		Rochester
Cli		Clinton
Me	Green Pond	Medina
On		Oneida
La	Land	Land
Ri		Richmond
Lo	Land	Lorraine
Fr		Frankfort
UT		UTICA
Tr	<-- Probably land -->	Upper Trenton
		Normanskill
		Lower Trenton
Bl		Black river
Lo		Lowville
St		Stones river and *Chazy*
BE		BEEKMANTOWN
PO		POTSDAM
Lo		Lower St Croix
La	GEORGIA	GEORGIA
La		VERMONT

Unclassified time scale for eastern North America, and correlation of formations and land intervals in the Mississippian, Appalachian valley, and Atlantic provinces, and their respective basins

The same name in two or more columns indicates direct marine and faunal connection either before or after the birth of the basin under which it is listed. Different names on the same line indicate supposed equivalence in age only.

Names of formations deposited in the Mississippian sea are printed in ordinary type, those laid down in Atlantic waters in *italics*, while names of those deposited when the Mississippian and Atlantic seas were in communication by way of the St Lawrence channel are printed in SMALL CAPITALS, and heavy face type is used for formations deposited in Atlantic waters that entered the territory of the Mississippian province by way of the Cumberland basin.

MISSISSIPPIAN PROVINCE	APPALACHIAN PROVINCE					ATLANTIC PROVINCE		GENERALIZED TIME SCALE FOR EASTERN NORTH AMERICA
		APPALACHIAN VALLEY TROUGH						
				LENOIR BASIN				
Mississippian sea	Chazy basin	Levis channel	Middle third	Knoxville trough	Athens trough	Cumberland basin	Skunnemunk basin	
Carbonic	Land	Carbonic	Carbonic	Carbonic	Carbonic	Carbonic	Land	Carbonic
Chemung		Gaspé series. For duration see the generalized time scale	Chemung			Chemung	Skunnemunk	Chemung
Portage			Portage			Portage		Portage
Genesee				? Chattanooga	Chattanooga		Bellvale	Genesee
Tully			Hamilton			Hamilton		Tully
Hamilton	Land						Monroe	Hamilton
Marcellus	Deposits not well known		Marcellus	Land	Land	Marcellus		Marcellus
Onondaga						Land in south		Onondaga
						Onondaga in north	Land	
Schoharie	Land					Schoharie		Schoharie
Decewville				Land	Land	**Esopus**	Esopus	**Decewville and Esopus**
Upper Oriskany				*Frog mountain*	*Frog mountain*	**Upper Oriskany**	Oriskanian	**Upper Oriskany**
Land	Land			Land	Land	*Lower Oriskany*		*Lower Oriskany*
	St Helens island					*Kingston*		*Kingston*
						Becraft	*Helderbergian*	*Becraft*
	Land					*New Scotland*		*New Scotland*
						Coeymans		*Coeymans*
Land								
Manlius in part		Land	See Cumberland basin			*Manlius*		*Manlius*
Land						Formations at Pinto Md.	? Land	*Decker Ferry*
Rondout								Rondout
Salina	Land							Salina
Guelph								Guelph
Lockport						No name. Formations at Cumberland Md.	*Longwood*	Lockport
Rochester	*Anticosti series*							Rochester
Clinton								Clinton
Medina						Tuscarora and Juniata	Green Pond	Medina
Oneida								Oneida
Land	Land					Land	Land	Land
Richmond	*Anticosti Hudson river*					Lower Rockwood		Richmond
						Clinch		
Lorraine	Land	Land	Land			Bays	Land	Lorraine
Frankfort	Frankfort	Frankfort	Frankfort	Land	Land		Probably land	Frankfort
UTICA	UTICA	UTICA	UTICA					UTICA
		Upper Trenton		Sevier	Sevier	See Middle third for previous deposits		Upper Trenton
Trenton	Trenton	*Normans kill*	Trenton					*Normanskill*
		Lower Trenton		Moccasin	Tellico			Lower Trenton
Black river	Black river	Black river	Black river					Black river
Lowville	Lowville	Part of time land	Lowville	Lenoir	Athens			Lowville
Stones river	*Chazy*	*Levis*	Land					Stones river and *Chazy*
BEEKMANTOWN	BEEKMANTOWN	BEEKMANTOWN	BEEKMANTOWN	BEEKMANTOWN	BEEKMANTOWN			BEEKMANTOWN
POTSDAM	POTSDAM	Land	POTSDAM	POTSDAM	POTSDAM			POTSDAM
Lower St Croix	Land	Middle Cambric	Middle Cambric	Middle Cambric	Middle Cambric			Lower St Croix
Land		GEORGIA	GEORGIA	GEORGIA	GEORGIA		GEORGIA	GEORGIA
Land	Land	VERMONT	VERMONT	VERMONT	VERMONT			VERMONT

Summary and general conclusions

Permanence of land masses and of folds of the earth's crust. Our studies tend to the conclusion that the present North American continent was in existence, and practically in full development as land, at the close of Algonkian time and that since that period, the Canadian shield and other smaller Archean land areas have never been wholly submerged. The periodic encroachment of the sea on the Canadian shield attained considerable extent on the north and west and more particularly on the south. The east shore, on the contrary, remained nearly the same till comparatively recent time—probably Postcretaceous.

The present main lines of elevation of the continent were in existence in Algonkian time and have been maintained without serious modification to the present day. Concerning the anticlinal folds that began in Paleozoic and later times, we think that all known evidence bearing on the point goes to prove that, following their inception, they, in common with those of older date, were never changed except 1) to be periodically accentuated, 2) to have their axes migrate slightly landward, like the summit of a wave, in correspondence with effects of active compression and subsequent gravitational adjustments, and 3) to be modified in their relations to the general plan of crustal folding by the development of folds of subsequent origin.

We agree with Walcott's conclusion that in Lower Cambric time the greater part of the interior of the continent was land, and that the first Paleozoic subsidence of the interior and the real birth of the Mississippian sea occurred with what we term the St Croix invasion.

Rhythmic pulsations. There is a rhythmic relation between the successive grand subsidences and emergences of the interior of the continent that we believe should be the basis of a revised classification of the rocks of North America. Such relation was indicated by Amos Eaton and later by Newberry and others. Each system should begin with a subsidence and end with an emergence. While such a classification will be in some respects different from the one now in use, and its adoption therefore

likely to be opposed, we do not doubt that it will prevail in the end because it will have a natural basis.

Depth of Mississippian sea. With the possible exception of the Beekmantown, we fail to see anything even approaching deep sea conditions in any of the sediments of the Mississippian sea. On the contrary, there is abundant evidence that during Paleozoic time the "shift of relative level" of the sea and land was never great outside of the area of the barriers described. Sometimes the sea was so shallow as to form tidal flats, in other cases the land was so near sea level that erosion was practically nil, but in other cases again, the land was high enough to be subject to erosive agencies, the effects of which are now more or less obviously preserved in unconformities of stratification. These unconformities however, are in but few cases so clear that the stratigraphic discordance may be recognized in any given exposure, but their recognition depends in most cases on the absence in a section of a zone or formation observed in other sections. Sometimes, as on the west flank of Cincinnati axis in middle Tennessee, where Upper Devonic or even Lower Carbonic may rest on Middle Trenton, the evidence of unconformity is so slight that without fossils it would scarcely be detected.

Principal submergences and emergences. The first pronounced Paleozoic submergence in North America resulted in what we have called the St Croix invasion. It embraced nearly all of that part of the Algonkian continent lying between the Rocky mountain protaxis and the Appalachian protaxis south of the Canadian shield. This subsidence gave birth to the Mississippian sea, and the movement accentuated a Precambric fold under the Lower Cambric sea extending from Alabama to Gaspé. The northern part of this fold we call the Green mountain barrier, while its southern half is termed the Chilhowee barrier.

The submergence inaugurated by the St Croix invasion culminated in Beekmantown or "Calciferous" time, when more of the continent was under water and the sea probably deeper than at any subsequent period.

The second important movement occurred at the close of the Beekmantown, when the Mississippian sea was restricted to much narrower limits, and possibly almost drained for a short time. With this emergence, which was unusually abrupt and far-reaching in its results, a new fold was developed along the western side of the Appalachian valley extending from Alabama to Newfoundland. This we call the Appalachian valley fold or barrier, its northern end being distinguished as the Quebec barrier and the southern end as the Rome barrier. There is some reason to believe that the Cincinnati axis or parma had its inception in this second movement, though it did not reach the surface of the sea till long after, i. e., about the close of the Black river.

The third pronounced movement occurred at the close of the Ordovicic, when the elevation begun at the close of the Frankfort culminated in the emergence of apparently the whole continent. It gave birth to the Taconic mountains and to a third long Appalachian fold, called the Helderbergian fold or barrier, that excluded the waters of the Mississippian sea from the Cumberland basin, which thereafter was occupied by Atlantic waters till the close of the Esopus.

The next invasion of the Mississippian sea began possibly very soon after the Richmond emergence, bringing in the Medina, Clinton, Niagara and Guelph faunas, the sea apparently spreading a little farther with each succeeding formation. Then a period of emergence set in, continuing in the Mississippian province till Onondaga time, if we disregard the geographically limited Helderbergian invasion of Tennessee and southern Illinois.

The period of submergence following this gradual emergence of the Mississippian province also was one of slow action, beginning with very late Oriskany or Esopus time and continuing apparently into the Lower Carbonic. However, considerable land areas were developed toward the close of the Devonic, so that the rocks of this system also bear evidence of, first a periodically progressing submergence and then an emergence like those more clearly shown for the preceding systems. Similar movements are indicated again for the Lower Carbonic and the Upper Carbonic.

Migrating shore lines. Two excellent examples of a migrating shore line are indicated by 1) the Stones river and 2) the Oriskany and Onondaga invasions. The first, apparently, came in from the south and west and progressed northwardly, reaching the Mohawk and St Lawrence valleys just before the close of the Stones river, the last division of that age being almost uniformly represented there by the Lowville limestone.

The second invasion was very different from that of the Stones river. It came in from both the Atlantic and the southwest, that from the former source advancing rapidly and laying down the coarse deposits of the Oriskany, that from the latter direction progressing apparently more slowly and laying down the limestones of Onondaga age; and, meeting, their respective faunas commingled in the Decewville formation described above.

Effectiveness of folds as barriers to seas. The Green mountains-Chilhowee barrier, the first and oldest fold west of the Appalachian protaxis, was not crossed by the sea from the close of the Beekmantown age to early Siluric time, but through the whole of Siluric and some of Devonic time it was ineffective as a barrier to the Atlantic, which passed over it probably in the region of Maryland. These same waters also crossed the Appalachian valley barrier, but a younger fold (Helderbergian barrier), lying to the west of the other two, still prevented the Atlantic from joining the Mississippian sea throughout the time from Medina well into the Oriskany. The union of the two seas, however, was effected during late Oriskany, in Marcellus and possibly again during a portion of Portage time (Genesee).

The Mississippian sea crossed the Appalachian valley barrier from southwestern Virginia northward to east central New York, excepting the intervals when the north Atlantic by way of the St Lawrence channel crossed it with the Normans kill and Utica deposits and faunas, from Lowville to close of Frankfort time. Previous to this time, and immediately succeeding the formation of the Appalachian fold, the Atlantic invaded the terminal thirds of the Appalachian trough, filling the southern Lenoir basin, which was confined between the effective Rome and Chilhowee barriers, while it occupied two narrow basins in

the north, the Levis channel on the east, the Chazy bay on the west side of the Quebec barrier. Though the Chazy bay extended some distance up the Ottawa valley, there was no communication between the Atlantic and Mississippian seas at this time, a great land area to the west of the bay affording effectual separation.

Communication between the Atlantic and the Mississippian seas occurred at least once besides the Normans kill, Utica, and Devonic connections just mentioned. We refer to the communication that probably began during late Upper Cambric and either continued through or was revived during Beekmantown time.

Basis for more exact faunal and phyletic studies. We have pointed out the Paleozoic periods when the Atlantic and Mississippian seas were separated from each other and also when they were in communication. The relations of the Mississippian sea to the Arctic, northern Pacific and Gulf of Mexico remain in great part yet to be determined. Reliable data are difficult to secure, yet they are not so few as to discourage the hope of ultimate success. When the more essential facts are known, paleontologists will learn to discriminate between the foreign and indigenous elements of our fossil faunas, and incidentally these new facts will throw much light on general geology and organic evolution. They will not then be so likely to arrange heterogenous specific elements as members of one line of descent, nor will they be so eager to identify or throw together species and genera that better and fuller information may prove to represent even different lines of development. The species and genera may have much in common, but the investigator will pause and look carefully into their derivation, both biologic and geographic, before he will feel justified in pronouncing them identical. In short, we shall secure more critical, and therefore more reliable results, and these will bear sound fruit, not only in the domain of pure biology, but also in stratigraphic geology. The farther we progress along the lines indicated, the more exact will our correlations become. Indeed, even extra-continental correlations are not beyond approximate exactitude.

THE INDIGENE AND ALIEN FAUNAS OF THE NEW YORK DEVONIC

BY JOHN M. CLARKE

This paper has been suggested by the important propositions presented in the preceding article which was prepared by Messrs Ulrich and Schuchert at the urgent solicitation of the state paleontologist. The existence of a Paleozoic Appalachian channel parallel to the orographic features of the eastern border is recognized by the writer as an indispensable factor to the proper apprehension of the sequence and geographic relations of the New York faunas. The full value of the considerations set forth by the accomplished authors will be better measured when time has permitted an adjustment of contending evidence by a more complete array of facts. In the following, however, it is in part intended to show, irrespective of the finer analysis of the shore topography, in what manner the Devonic faunas of New York indicate the influence of such Appalachian channel.

By an indigene fauna is meant, in this paper, one which, taking possession of the marine province at an early date, held the ground (subject to variations in its species combination) for a long period, during which may have occurred various minor invasions. This is the correct significance of the term, as every indigene fauna is alien in its inception.

The Appalachian gulf, or marine water of the New York Devonic, had its northern coast line at the opening of this period probably not far south of the present south line of Lake Ontario and the course of the Mohawk river. This statement is made assumptively, as the northern shoreward edges of the sediments of the period have been removed. We may say with some assurance that this continent line was no farther south; it may however have been situated

somewhat more to the north, specially in its westerly extent. In the vicinity of Albany the coast line turned to the south and bent along the present trend of the Appalachians wherever the latter are indicated by topographic features or structural details. At the commencement of Devonic time the Appalachian gulf was a great embayment, opening widely to the northwest and southwest into the Mississippian sea and submerging all the western and central areas of New York and the southeastern area west of the Silurics of Orange and Sullivan counties. The northern coast line spread widely to the northwest through Ontario and Manitoba, the southern extended down the Appalachians through Pennsylvania, Maryland and Virginia. Outside and eastward of the gulf, separated therefrom by a narrow land bar, was, we may confidently believe, in accordance with Messrs Ulrich and Schuchert's deductions, a stretch of water probably of no great width as far as Albany, likewise extending parallel with the Appalachian trend. From the evidences of early Devonic rocks in Massachusetts, New Hampshire and Maine we have reason to believe this area widened irregularly to the Atlantic and passed far beyond the head of the gulf to the northward. Southward down this waterway traveled the congeries of species which in the early Devonic entered New York from a center of prolific development and departure in Gaspé and New Brunswick, and in Siluric times from regions of the east still more remote. This is a condition which had existed long before the Devonic, and the same waters had served as a passage for the migration of species into eastern New York. While the early Devonic saw the continuance of the condition, the later stages of the time witnessed its disruption and discontinuance.

Helderbergian fauna

The earliest of the Devonic faunas of New York is that of the Helderbergian. Geographically the Helderberg sediments, as shown by Ulrich and Schuchert, were laid down east of the land barrier and on the west shore of the Appalachian strait and in our view, also along the widening northern opening of this

passage out into a broad and deeper gulf extending to the northeast continuously or discontinuously to beyond the coast of the maritime provinces. In this deepened head of the gulf the Helderbergian fauna, traveling southward from a long sojourn in inchoative condition in the region of the Gulf of St Lawrence, adding vitality and prolixity on its way (as shown at Dalhousie N. B.), sequestered itself in deepening water and was fruitfully multiplied to its climax. The Helderberg fauna as a whole was thus an invader from the northeast. The narrow bar which separated its first assession from the Appalachian gulf was in a state of degradation so extensive that, at the earliest period of its presence, transgression over this barrier was readily effected, but not a transgression which extended far, as the barrier remained an obstacle to free migration.

The Helderbergian, however, did not gain possession of an extensive area in New York during its earliest manifestations, its species commingled in some measure with the frail Siluric congeries on the ground of central and western New York which had endeavored to reinstate itself with the gradual freshening of the Salina sea, but in later stages of its existence the reintegration of the barrier shut out from the area of the Appalachian gulf all evidence of its final phases (Becraft, Kingston (=Port Ewen) beds). The area of the Helderberg in New York was its fruitful center of dispersion, and thence its travels were southward along the barrier, probably around its southern termination, and from there into the Appalachian gulf in the region of western Tennessee, Illinois and Indian Territory.

Oriskany fauna

From the same direction and along the same thoroughfare came the Oriskany, its center of variation and dispersion unquestionably being in the region of Gaspé bay, where now its species are dispersed through 800 feet of limestone. Leaving behind it species which may have survived in the Gaspé sandstones to a later period of Devonic time, it followed in the train of the Helderberg fauna, manifesting itself most perfectly in the silicious limestones of Columbia and Ulster counties.

Naturally its fauna includes some Helderbergian species, partly picked up in its travels hither from Gaspé and partly found on the ground on its arrival in New York. As pointed out in our previous studies of this fauna, its species trangressed for a very brief period the eastern limits of calcareous deposit and spread themselves westward over the irregular, deeply embayed and probably rocky coast line of central New York and Ontario.

Onondaga fauna

Primarily this fauna is of reef-building corals, and entered the state from the west, where its reefs and attendant organisms attained their greatest prolixity. The lessening and disappearance of the coral facies eastward and the final loss of the limestone deposit evince this derivation. Any submarine barrier in the east however was so deeply submerged at this epoch as not to interfere with the deposition of chert-bearing limestone in Columbia county east of the Hudson river. The east presents in the arenaceous beds of the Cauda-galli and Schoharie grit a facies which is not elsewhere seen. In clastic character, there is excellent reason for associating these beds directly with the deposition of Oriskany sediments as a closing stage thereof, and indeed several elements of the striking Schoharie fauna indicate derived relations to the Oriskany. This might be predicated of the trilobites specially, of the brachiopods and lamellibranchs in part, but not of the most conspicuous element of the fauna, the cephalopods. For the origin of the latter we have yet to search; they may have entered New York from the west with the fauna of the limestone and have wandered into the shallow waters where Schoharie sediment was depositing; they may have, on the other hand, come in from some source, northeast or southeast, as yet unknown to us, and hence be related ancestrally to similar forms of the overlying Onondaga limestone. Present evidence seems to favor the former conclusion without disparagement to the genetic relations of these cephalopods to those of the Onondaga. It seems justifiable however to assert that the fauna of the Onondaga period as a whole, with its noteworthy coral, trilo-

bite, cephalopod and gastropod facies unequally developed locally, is a complex congeries, largely from the western reaches of the Appalachian gulf, but freely inoculated with elements genetically from the northeast. The latter may have come in directly, geographically and genetically, through the Oriskany province of eastern New York or indirectly into the western limestones, after migration from New York southward to the end of the barrier and thence into the heart of the gulf. The latter seems specially probable of the gastropod element.

Marcellus fauna

As the Onondaga limestone fauna came in from the west, so it withdrew westward. In the latest stages of its immigration it brought in the cephalopod Agoniatites expansus; but when this species had penetrated to eastern New York this ground had been occupied for some time by shallowed and foul waters, wherein were depositing the black muds of the Marcellus shale with its accompanying singular fauna. Early Marcellus deposits in eastern New York were thus contemporaneous with late Onondaga deposits in western New York. This being true, the Marcellus fauna entered the New York area of the gulf from the southeast or from the direction of the eastern shore. The effect of the putative eastern barrier and its accompanying northeast channel is now no longer perceptible save as we ascribe to the submergence of the latter in part the befouling of the waters.

Fauna of the Agoniatites limestone

It has just been stated that Agoniatites expansus came into New York from the west in the closing stage of Onondaga time. The limestone to which it appertains forms a very distinct band in the Marcellus section of eastern and central New York, and associated with it is a small and exclusive congeries of species, with some which belong to the fauna of the shales. So far as concerns the peculiar species which characterize the fauna, they have probably all been derived from the same direction at the same time as Agon. expansus.

Hamilton fauna

Fauna of the Stafford limestone

This is another and higher limestone bank in the Marcellus shales, but extends no farther east than Ontario county, while the Agoniatites limestone goes no farther west as a limestone than the same meridian. The Stafford limestone contains the earliest extensive representation of the normal fauna of the Hamilton stage. This is not actually the earliest appearance of the fauna, for a calcareous layer just at the base of the Marcellus shales in western New York also carries Hamilton species commingled with others surviving from the Onondaga fauna, but the Stafford affords a pure Hamilton fauna. The incursion of this congeries in this manner is very significant; the limestone and its contents are lost east of Ontario county, but from there to the western limit of the state its course is unbroken. Thus it clearly indicates that the Hamilton fauna, both in this prenuncial expression and in its normal return, after its retreat had been covered by a considerable period of deposition in the gradually clearing Marcellus waters, entered the state from the west; whether from the northwest, through the opening of the shore line up through Manitoba and thence westward through Siberia to the Ural Devonic sea, or up from the south, skirting the Devonic shore line of eastern South America, where it arrived by shore from Africa and its center of dispersion in Belgium and the Eifel or, again, along the assumed north Atlantic land line, can not yet be determined.

Tully fauna

This fauna is essentially constituted of derivatives from the Hamilton with the addition of two brachiopods of world-wide distribution, Hypothyris cuboides and Schizophoria tulliensis (cf. S. striatula Schloth.). The former is an excellent index fossil of the lowest Upper Devonic, the latter a belated newcomer of Middle Devonic habit. So far as the special expression of the fauna imparted by these two species is concerned, it does not elsewhere manifest itself in

eastern America; but there is abundant evidence to show that the species themselves have come into the gulf by the northwest passage.

Naples fauna

This is the fauna of the Styliola limestone embedded in the black Genesee shales and of the Portage beds of western New York, ranging up to and beyond the summit of the original Portage sandstones. The fauna is distinctly an invader from the northwest.[1] It has almost naught in common with the Hamilton fauna which preceded it on the ground, but is a congeries of oceanic organisms which together constitute the zone of Manticoceras intumescens, well marked in many parts of the world but nowhere with a more prolific fauna than here. Eastward of Cayuga lake its integrity is lost by mergence with the contemporaneous Ithaca fauna. The migration path of this pelagic fauna has been traced toward the northwest through Manitoba into Siberia, thence through Russia into Westphalia. Where it was originally autochthonal is not certain; perhaps Westphalia was its home, but in New York, where its fauna became extensive, it was alien and short-lived.

Ithaca fauna

Contemporaneously with the Naples fauna in western New York the Ithaca fauna held the field in central New York approximately, except in its latest stages, from Cayuga lake on the west to the Chenango valley on the east.

The Ithaca fauna is genetically sequential to the fauna of the Hamilton epoch. Its species are at first identical with those; then variations superinduced on these specific types manifest themselves, and in the event the fauna in its totality is clearly distinct from its ancestor. Hemmed in on the east by the barrier which made the Oneonta waters a lagoon, and on the west by the invading Naples fauna, it found favorable opportunity for multiplication and variation on ancestral

[1] The authors of the preceding paper regard the Naples invasion as from the Atlantic. This is an assumption unsupported by any evidence known to the writer.

ground. It is indigene, for its ancestry had taken and lost possessions early in Marcellus time by invasions from the west, retaken and held possession from the beginning of Hamilton time. It is to be noted that through a part of the extent of the Ithaca sediments there is nothing separating them from the Hamilton beds below, the Tully limestone and Genesee shale feathering west of the Chenango valley.

Oneonta fauna

Contemporaneous with the latter part of Ithaca sedimentation was the sparse fauna of the Oneonta sandstones. These we believe to have been deposited in a narrow coastal lagoon, and its few characteristic organisms, Amnigenia catskillensis, Estheria membranacea, are of fresh-water habit. The latter occurs in the Old Red lakes of northern Scotland, species of the former in nonmarine deposits of Ireland and the Eifel. We are left to surmise that these species found their way into New York by fresh or brackish water passage from the Old Red lakes of Nova Scotia (Arisaig) and Quebec (Gaspé).

The Catskill. The Catskill represents a continuation of Oneonta sedimentation; that is, deposition in a deep embayment but with freer access to the open waters of the gulf, thus constituting a long and narrow estuary extending far southward parallel to Appalachian trend. It may well be compared to the conditions now existing in the Lake of Stennis in the Orkney mainland as described by Hugh Miller, in which the upper reaches are fresh and bear a fresh or depauperated brackish water fauna while the lower parts are salt and marine. We know that this condition (including the deposits of the Oneonta) prevailed in eastern New York from the close of the Hamilton through Portage and Chemung time and in southern New York continued into the early Carbonic.

Chemung fauna

The main body of the Chemung fauna is the direct derivative along the long line of descent from the Hamilton through the

Ithaca fauna. As a benthonic littoral congeries, chiefly of lamellibranchs and brachiopods, it has acquired variation with age, and, on the removal of the obstructions to migration which prevailed in Ithaca time, it disseminated itself eastward to the Catskill embayment, probably over it at times and westward beyond the limits of the state. It also spread over the heart of the gulf and along its southward shore. From this, its home province and center of dispersion, departed, or to it were added, certain widespread species, such as Spirifer disjunctus and the glass sponges. It is however as a whole the last expression of the single New York fauna of Devonic time which may be properly characterized as indigene.

EXPLANATION OF PLATES

Plate 3

Thamnocladus clarkei White

Page 596

FIG.

1 Greater portion of a large frond partly buried in the matrix. The segments are somewhat macerated and show the effect of current dragging. Natural size. Chemung, at East Windsor N. Y. New York state museum.

LGA

G S Barkentin.del

Phil. Ast, lith.

PLATE 4

Thamnocladus clarkei White

Page 596

FIG.

1 Portions of several segments, probably belonging to the same frond or the same tuft. The different portions lie at different levels in the bed, the larger ones passing out at the back side of the slab. Natural size.

Same slab as pl. 3.

2 Isolated portions of two segments showing more distinctly the mode of division, the aspect of the terminal portions and the lamina. Natural size.

Catskill at Factoryville, Wyoming co. Pa. No. 25072, Lacoe collection, United States national museum.

CHEMUNG ALGA

2

1

G S Barkentin del

Phil. Ast. lith

PLATE 5

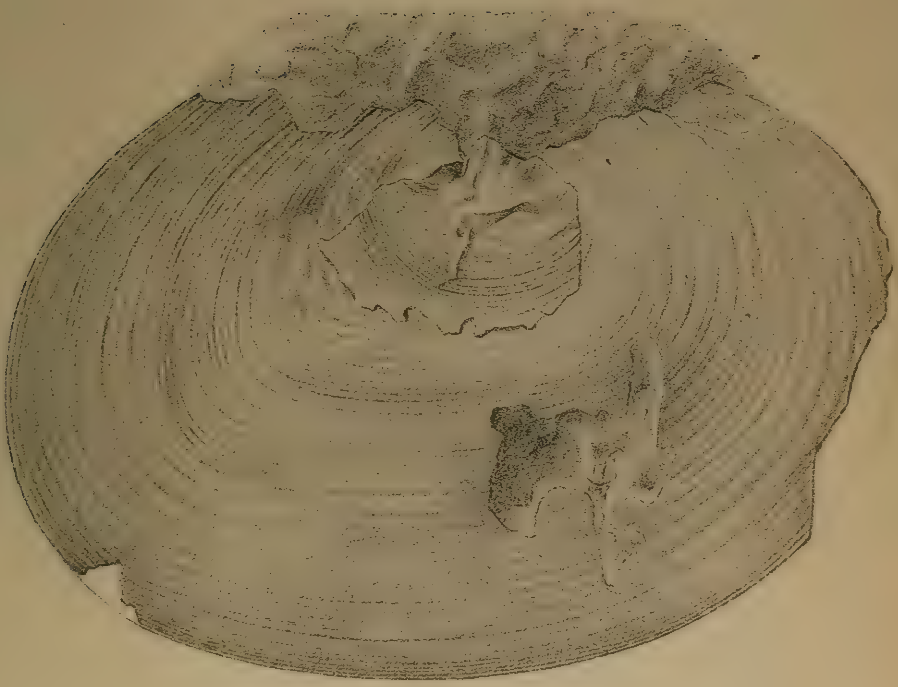
Eunoa accola Clarke

p. 607

(*See* pl. 6)

FIG.

1 A large brachial valve incomplete at the posterior edge. Beekmantown graptolite shales. Deep kill, Rensselaer co., N. Y.



G S. Barkentin. del. J. B. Lyon Co. State Printer Phil. Ast, lith.

PLATE 6

Eunoa accola Clarke

p. 607

(*See* pl. 5)

FIG.

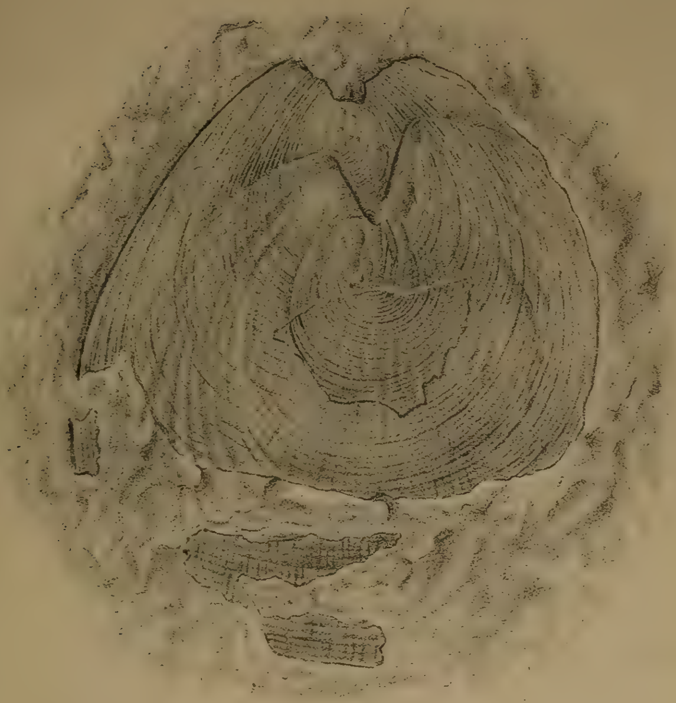
1 Two valves overlapping and exposing the pedicle notch with clearly defined margins. The posterior margin of the brachial valve is here again not clearly defined.

2 A pedicle valve with the margins of the pedicle slit approximately entire for most of their extent, though pressed apart.

Beekmantown graptolite shales. Deep kill, Rensselaer, co. N. Y.

EUNOA.

1



2

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PLATE 7

Orbiculoidea ? magnifica Clarke

p. 615

(*See* pl. 8)

FIG.

1 The half of an infolded pedicle valve showing the pedicle opening extending for the full radius of the shell. The margin of the infolded portion of the valve is visible at the periphery of the shield.

Portage beds. Tannery gully, Naples N. Y.; at an horizon just above the final appearance of the Naples fauna.

ORBICULOIDEA.

G. S. Barkentin. del. J. B. Lyon Co., State Printer. Phil. Ast, lith.

PLATE 8

Orbiculoidea ? magnifica Clarke

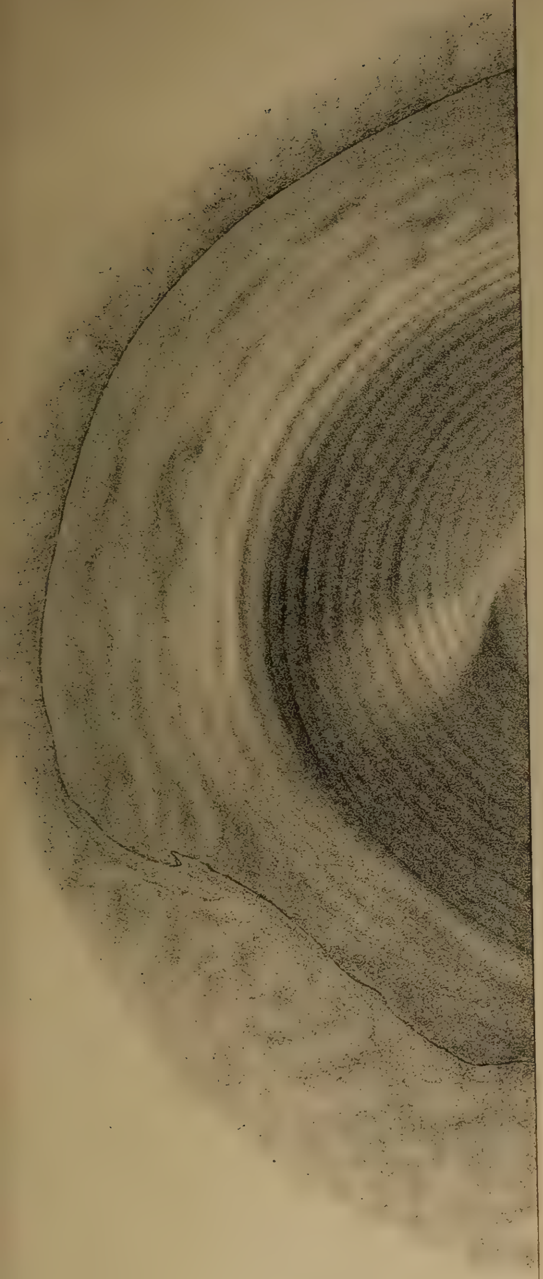
p. 615

(*See* pl. 7)

FIG.

1 A large depressed conical shield believed to represent the brachial valve of this organism. Drawn from a plaster cast.

Ithaca beds. Truxton N. Y.



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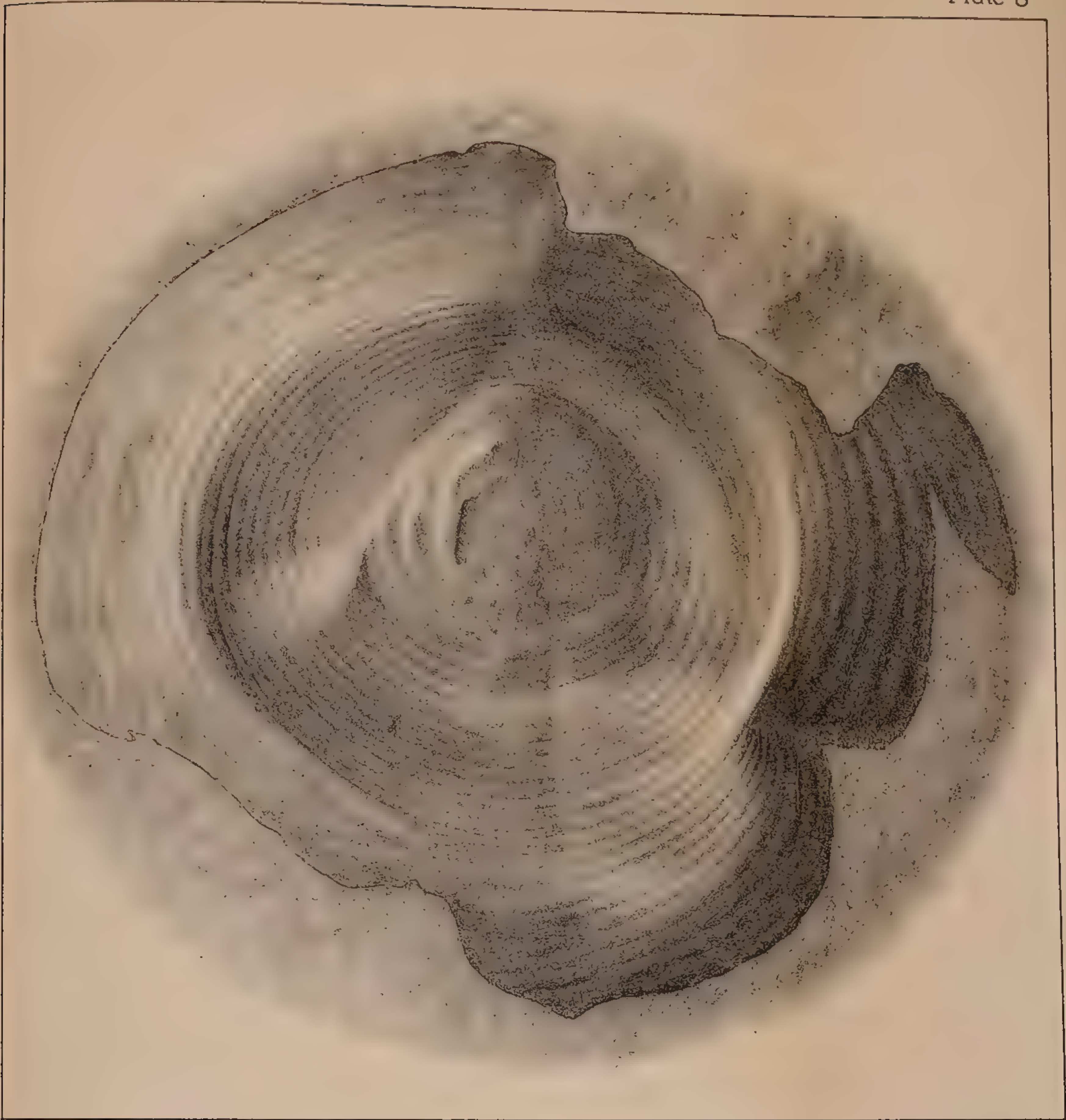
Rep Paleontologist 1901.

Plate 8



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INDEX

Page numbers referring to descriptions of fossils are printed in black face type. The superior figures tell the exact place on the page in ninths; e. g. 623^3 means page 623, beginning in the third ninth of the page, i. e. about one third of the way down.

University of the State of New York

New York State Museum

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Entomologist's annual reports on the injurious and other insects of the State of New York 1882–date.

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16–17	50 "	26–31	53 "	37–44	" v. 3
18–19	51 "	32–34	54 "	45–48	" v. 4

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